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People Powering Progress: How Human Resource Influences Your Company's Digitalization and Sustainable Growth

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Abstract

The digital world holds many opportunities and challenges for us. These changes affect all the basic pillars of sustainability, including the economy, society, and the environment. They primarily affect companies, specifically their productivity and profitability, so it is not an exaggeration to say that nowadays, we can consider the digital maturity of companies as one of the driving forces of the economy. The research aims to prioritise the digital competence of the workforce among the indicators of digital maturity, which, based on my hypotheses, has the greatest impact on the profitability of businesses. Another main research goal is to map the cognitive sustainability-related activities of human resources employed by companies and then present the relationship between digital maturity and sustainability through human resources.

In this study, the digital maturity of companies was assessed, especially the role of human digital skills in productivity based on Maslow's business pyramid and a SWOT analysis. I compared the cognitive sustainability-related activities of human resources and examined how this affects the company's effectiveness.

Keywords

digitalisation, sustainability, cognitive sustainability, human resources, enterprises

1. Introduction

Digital transformation holds countless opportunities and challenges for today's society. Since society and its environment are constantly changing, these new challenges and opportunities, as well as the adaptation to them, greatly influence the future of society (*Szabó et al., 2018*).

In addition to society, digital transformation also significantly influences the other pillars of sustainability, the economy and the environment (*Zöldy et al., 2022*). It follows consistently from these that digital transformation forces companies to make continuous changes to maintain their competitiveness and profitability (*Vaz, 2021*). Information and communication technologies, big data analyses, and digital technologies offer many new opportunities but at least as many challenges for existing companies (*Kache and Seuring, 2021*).

Digital maturity has become the basis of companies' competitiveness. The most important factor for companies is the person himself (*Vaz, 2021*). Digital transformation induces small challenges in companies every day, which company leaders must consider. These developments also enable the collection and analysis of data, which is now indispensable for companies (*Herbert, 2017*). The development of the digital maturity of companies is not a sudden, one-step process. It consists of many small innovations from which ideas about digital transformation are born (*Denicolai et al., 2021*). When considering these, they influence the company's business strategy and set priorities with their help. (*Szalmáné Csete, 2022a*). The basic condition of digital maturity is the assessment of organisational maturity according to how and at what level the company stands as a psychological organisation and an individual. One of the drivers of digital maturity is the digital competence of human resources (*Jukić et al., 2022*). We can say that human resources for companies are the joint appearance of people and technology. These are no longer optional concepts (*Schuler et al. 1993*). Knowledge is power.

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This statement is more relevant today than ever (*Toffler, 2022*). Thanks to digital developments, expanding experiential learning has become possible and increasingly important (*Kolb, 2014*). In a fast-paced and ever-changing world of development, information overload, and societal complexities, cognitive sustainability has become a critical framework for promoting resilience, adaptability, and long-term cognitive health (*Zöldy et al., 2022*). The goal of cognitive sustainability is to make the concept of sustainability describable and to be able to determine its essence, fairness and consequences (*Zöldy et al., 2022*). With the development of cognitive functions, the limits of environmental resources became more and more assessable, which became an important factor in corporate competitiveness (*Szalmáné Csete, 2022b*). The reason for this is to learn about consumer motivations. To do this, stakeholders constantly collect consumer data, analyse them thanks to digital developments and define consumer behaviours more precisely (*Majerova, 2022*). Consumers change their environment with their activities, and this has a strong impact on companies. Therefore, companies must use resources more efficiently and effectively (*Haddock-Fraser et al., 2010*). Today's generation is particularly sensitive to the possibilities of cognitive sustainability. Many of them struggle with climate anxiety, which affects the social sphere and the activity and financial stability of the economy (*Ojala et al., 2021*). For the future of society, the digital maturity of human resources, their view on cognitive sustainability, and their integration are crucial (*Zhanbayev et al., 2023*). Integrating these into our way of thinking, economic models and technological developments contribute to achieving the goals of sustainability and increasing the competitiveness of companies that quickly apply them (*Szalmáné Csete, 2022a*)

This research seeks answers to the following hypotheses. Firstly, among the indicators of digital maturity, the digital competence of human resources has the greatest impact on the profitability of businesses. Secondly, the cognitive sustainability-related activities of the human resources employed by the companies affect their competitiveness and the achievement of their sustainability goals.

2. Data and methods

This research is based on the application of two methodologies. It applies Maslow's needs pyramid to businesses and conducts a SWOT analysis.

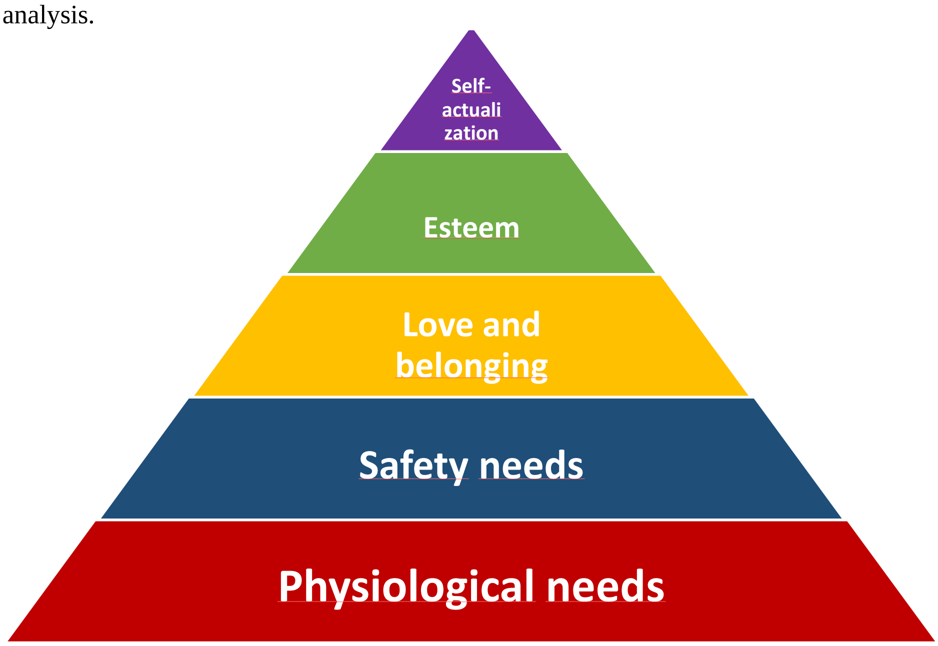

Figure 1. **Business Maslow's Pyramid**

Source: own editing based on Tay and Deiner (2011)

Based on Maslow's pyramid above, I classified the experiences and needs of human resources related to cognitive sustainability and the opportunities available by developing digital competencies.

Maslow believed in the need for cognition and understanding (Yadolla, 2009). According to the American psychologist Abraham Maslow (1908–1970), humankind's main motivation is to satisfy their needs. To prove this, he conducted research, which was the pyramid of needs. He presented this theory 1943 in his article *The Theory of Human Motivation*. The focal point of his theory is that all people desire self-actualisation, but their basic needs must be met (*Majerova, 2022*). Self-actualisation can be achieved when basic needs are already satisfied. Maslow assumes that individual behaviour is decisively

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determined by the degree to which an individual's needs are satisfied. According to his theory, if a person cannot satisfy one of his basic needs, he will not be able to satisfy other, more complicated, complex needs. These needs depend on each other, which is why they can be represented in the form of a pyramid (*Fig. 1.*). While deficit-motivated behaviour can be observed in the first four levels, growth-motivated behaviour can already be found in the fifth level (*Beck-Bíró, 2009*).

The first level is the biological to physiological needs necessary to stay alive: food, drink, air, and sleep.

The next level is the level of safety needs, it can be fulfilled by society or family: law and order, emotional security, health.

The third level is the love and belonging needs. It refers to human relationships: friendship, trust, acceptance, and love.

The esteem level includes self-esteem, achievement, and respect. We distinguish two parts of this. One is the individual's self-esteem; the other is the desire for reputation or respect from others.

The self-actualisation needs are at the highest level. This need level includes the person's full potential and the realisation of this potential (*Mcleod, 2024*)

By understanding Maslow's pyramid of business, companies can create a more motivated and productive workplace. The basic pillars are the same as the Maslow pyramid, but the needs supplement the needs belonging to each pillar through business. Physiological needs are supplemented with competitive salaries and flexible work in the business world. The safety needs include a safe work environment and job security in this model, which is important for the employee. We could see that during the COVID-19 epidemic, this point became the basis of needs. Needs for love and belonging in the workplace mean that colleagues can connect. The company can easily contribute to this with team-building events and a pleasant working atmosphere, achieving strong employee cohesion and a corporate culture where people enjoy working. The esteem level includes the recognition and reward of employee performance. The highest level of self-actualisation needs include providing opportunities for personal and professional growth. This contributes to the reduction of employee fluctuation (*Peak Frameworks, 1998*)

The SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) is excellent for assessing these four aspects of businesses. The SWOT analysis is a tool used to identify a company's current competitive advantages over its rivals and to reveal weaknesses that should be improved to maintain or gain a competitive advantage. It takes into account both internal and external influences. This way, opportunities and threats outside the company can also be mapped.

3. Results and discussion

I divided the research results into three subsections based on the applied methodologies. First, based on the business Maslow's pyramid method, I explored the digital competencies of human resources influencing the company, and then I examined the experience factors related to cognitive sustainability. I analysed the effects of the digitalisation capabilities of human resources and their knowledge about cognitive sustainability with a SWOT analysis from the point of view of companies' competitiveness.

Cognitive sustainability promotes lifelong learning, a fundamental pillar of cognitive health and well-being. Lifelong learning encourages individuals to engage in continuous education, skill development, and intellectual exploration. With a curiosity, growth, and adaptability mindset, individuals can remain active, flexible, and receptive to new knowledge, ideas, and experiences, thereby developing cognitive agility and problem-solving skills.

Using cognitive sustainability, creating the right environment can promote cognitive function, creativity, and overall well-being. Exposure to a variety of sensory stimuli, engaging cultural activities, natural environments, and interactive technologies can stimulate cognitive processes, promote creativity, and enhance cognitive flexibility, activating a vibrant and healthy mind (*UGreen, 2024*)-

Cognitive sustainability includes social cohesion, positive social interactions of individuals, shared experiences, knowledge, and skill development. Digital transformation contributes to this. Thanks to digitalisation, we can develop our skills for a lifetime, easily expand our knowledge, and share our knowledge with others. Based on Maslow's business pyramid, described in the methodology, cognitive sustainability is present at all five levels. At the physical and security level, basic needs, the resources required, and their security are of primary importance to the individual. At the level of togetherness, close cohesion between individuals appears, for example, in friendships or family relationships. At the Esteem level, relationships based on respect for others, trust, and individual performance appear as an important indicator of cognitive sustainability to preserve mental health. The highest level includes creativity, stress reduction, easier problem-solving, and self-realisation, which are considered some of the most important indicators. Digital maturity is essential for developing cognitive skills. For example, it strengthens family and friendship relationships at the belonging level, even if there is a large physical distance between family members or friends, or it increases performance and knowledge by developing digital skills at the esteem level. On the other hand, the greatest emphasis is placed on the level of self-

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actualisation since digital maturity increases cognitive creativity thanks to the various platforms, and the solution to any problem is simplified thanks to digital networks.

Cognitive sustainability and digital maturity impact individuals, influencing their knowledge, skills and abilities, attitudes, and motivations, but they do not always emphasise the same factor. Companies must assess and develop these indicators to increase competitiveness. Based on Maslow's business pyramid, the relationship between cognitive sustainability, digitalisation and human resources can be represented below (*Fig. 2.*):

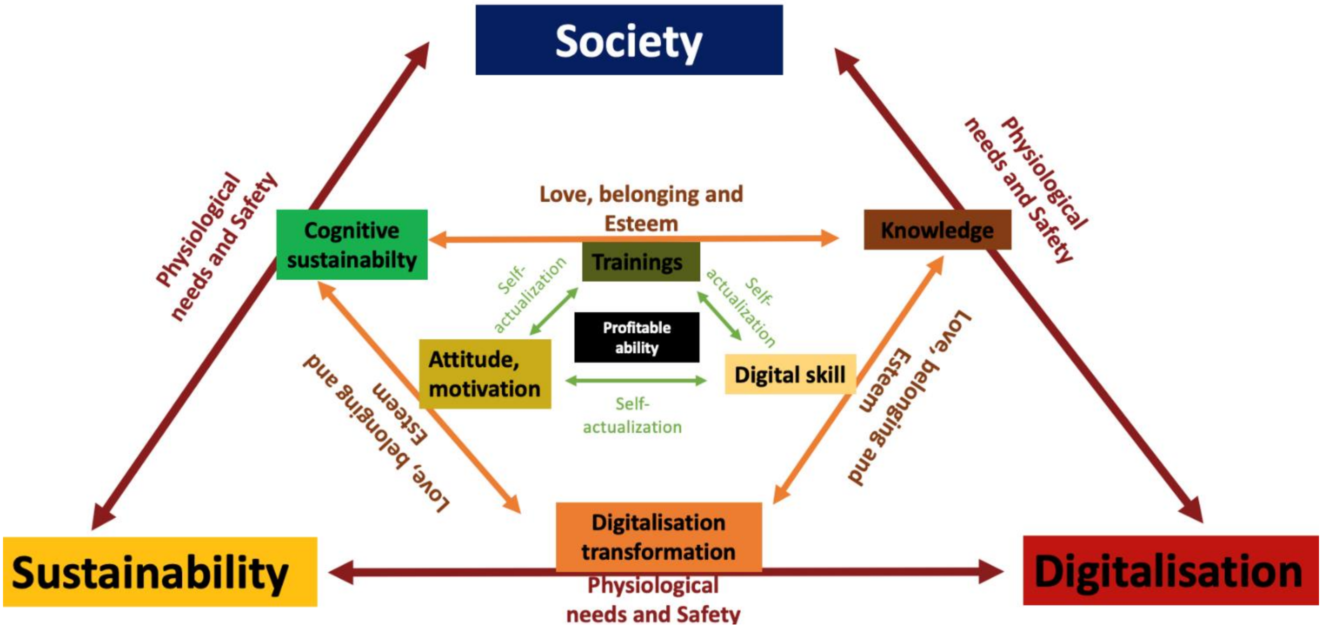

Figure 2. **The role of human resources in increasing digital maturity and sustainability is based on the Business Maslow Pyramid**.
Source: own source

The second research methodology of this study is the SWOT analysis. Based on the factors determined by the first methodology, I examined the external and internal factors of digital competence and cognitive sustainability experiences of human resources from the companies' point of view. We can only influence the internal factors from the company's point of view, but we should not neglect the assessment of external factors either, as this makes it easier to adapt and gain a competitive advantage.

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Table 1. SWOT analysis of human resources' digital competence and cognitive sustainability experiences
Source: own source

	Strengths	Weaknesses
Internal	• shared knowledge • skills and abilities development • attitude and motivation • digitalisation competence • strong workplace cohesion • cognitive sustainability knowledge • loyalty to the company • mostly stress-free work, avoiding the risk of burnout • More transparent and detailed communication with human resources • use the available applications (for example, phone number recognition for the company's phones	• fluctuation of developed workforce • dissatisfaction arising from environmental awareness • training a new competitor, especially in the Small and Medium-sized Enterprises sector
	Opportunities	**Threats**
External	• increasing creativity arising from the environment • municipal environmental protection measures at the company headquarters • green environment	• the geographic location of specialists • digital challenges for the older colleague • the appearance of competitors following new digital and sustainability principles on the market • climate anxiety

As it appeared in the results of the SWOT analysis, the competitiveness of companies depends significantly on the capabilities of human resources and their spatial location. In rural areas, the number of students studying sustainability and ICT professionals is significantly lower, which is a significant source of danger from the point of view of corporate competitiveness (*Fig. 3.*), In the two rural regions, nearly as many people are studying a sustainability or environment-related major as in Budapest. The data are available on the websites of Eurostat and FELVI.

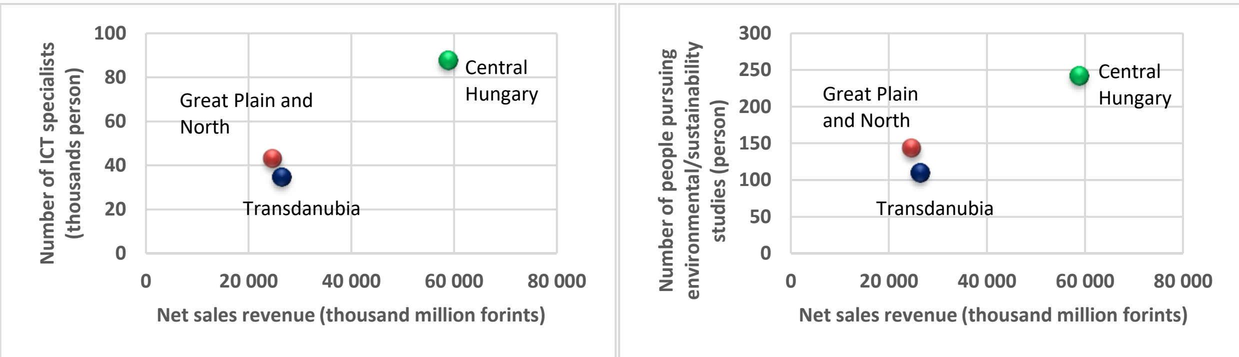

Figure 3. **ICT specialists and students of environmental studies**
Source: own source based on 2018 data

Based on these research results, the flowchart below illustrates the role of human resources in companies' digitalisation and sustainability efforts.

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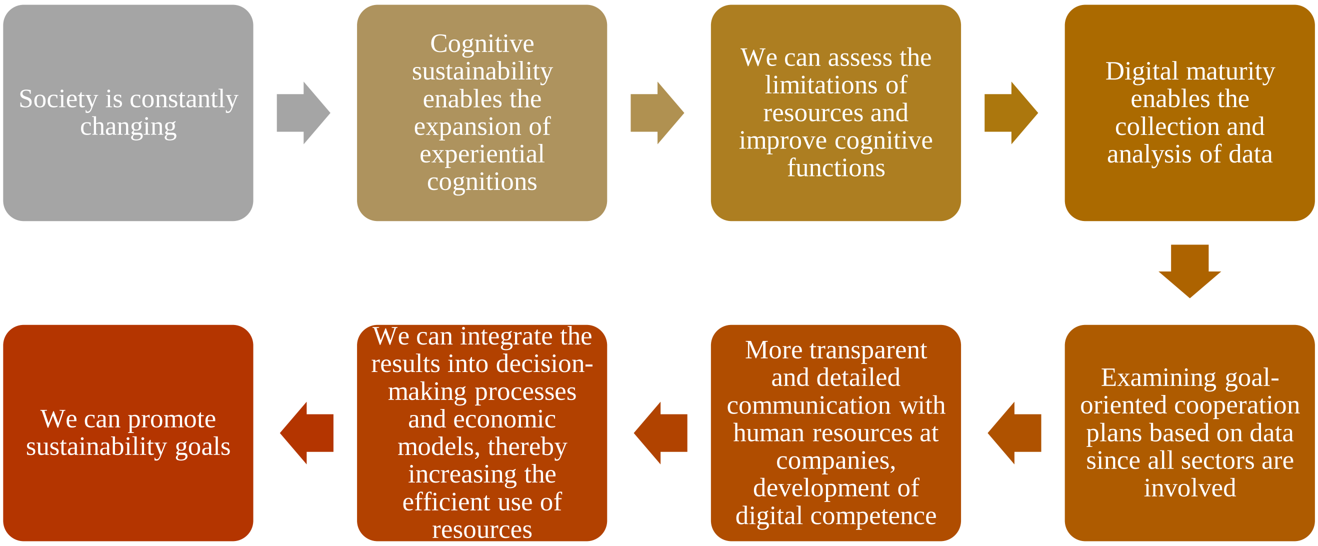

Figure 4. **The role of human resources in companies' digitalisation and sustainability efforts**

Source: based on own research

4. Conclusion

The research carried out in the study examined the role of human resources as a function of the companies' digital maturity, emphasising their influence on their competitiveness.

First, I examined the importance of the digital competence of human resources from a company point of view. Then, I scrutinised the connections between human resources and cognitive sustainability. Then, looking at the three factors together, I analysed the data and made a SWOT analysis, which summarises the knowledge of human resources related to cognitive sustainability and the importance of digital competencies.

Society is undergoing continuous change, which has accelerated even more today. Cognitive sustainability makes it possible to expand experiential knowledge, which is essential for today's people to understand the concept of sustainability better and to get closer to achieving sustainability goals. Thanks to recognition and its extension, we can assess the limitations of resources and improve cognitive functions. Developing competencies related to digital maturity enables an increasingly broad data collection and analysis. Since the most important factor of every company is the person, based on the available data, I examined the levels of Maslow's business pyramid, classified the factors of cognitive sustainability and digital maturity, and then depicted this in a process diagram that shows the digitalisation competencies, human resource characteristics, company profitability and includes corporate sustainability. With the development of digitalisation, more transparent and detailed communication can be achieved between management and company employees. This is essential for competitiveness. The research results can be incorporated into the company's decision-making processes and economic models, thus increasing the efficient use of resources and promoting the realisation of sustainability goals.

Overall, digital maturity enhances the competitiveness of companies by enabling fluctuation prediction, facilitating fluctuation prediction, more detailed, transparent communication, and motivating colleagues to use corporate applications. It is important to highlight that among the indicators of digital maturity, the digital competence of the workforce has the greatest impact on the profitability and competitiveness of enterprises.

Based on the results, it can be concluded that within the framework of cognitive sustainability, experiential knowledge of human resources can be expanded, and the understanding of the essence, fairness and consequences of sustainability can be enhanced, thereby making use of resources more efficiently and effectively. Therefore, the cognitive sustainability-related activities of the human resources employed by the companies have a significant impact on the companies' competitiveness and achieving their sustainability goals. However, just as companies' competitiveness depends significantly on human resource capabilities, the dependence on their spatial location cannot be neglected either. The number of trainings for

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sustainability specialists and ICT specialists is significantly lower in rural areas, which is a significant source of danger in terms of corporate competitiveness. Developments based on these results can reduce regional differences.

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Understanding Gen Z's Climate Anxiety: A Look at the Latest Research

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Abstract

Nowadays, the widespread availability of information on climate change has made up-to-date knowledge in this area more accessible to a broad section of society. At the same time, this information overload can potentially threaten psychological well-being. In particular, a specific form of anxiety, commonly known as climate (change) anxiety, is a substantial problem. Although climate anxiety terminology only became commonplace a few years ago, the phenomenon itself has older roots. It includes several responses to climate change, the complexity of which assumes more detailed knowledge. The fact that climate disasters are becoming more common may generate intense negative emotions such as fear, depression, tension, and rage. According to current studies, stress derived from climate change is most prevalent among Generation Z. This generation group is the focus of researchers due to their outstanding environmentally conscious approach. They are possibly expected to make the most important decisions in the future, and worries about climate change may significantly influence their decisions. Researchers need to analyze the multiple causes of this phenomenon and the actions they induce. This economic literature review aims to summarize the main observations from the international literature in this field.

Keywords
climate change, sustainability, climate anxiety, generation Z, psychology

1. Introduction

The terminology of climate anxiety was introduced only a few years ago, even though the phenomenon has been around for much longer and has a significant impact on individuals' climate attitudes and mental and physical health. This concept encompasses a wide range of climate change responses (*Clayton and Karasia, 2020*), the complexity of which requires an in-depth interpretation. The climatic disasters that frequently occur today have a serious impact on individuals' mental health (*Haines et al., 2006; Berry et al., 2010; Martiello and Giacchi, 2010; Xu et al., 2013*), as well as their physical condition (*Clayton and Karasia, 2020*). As a result, such disasters can be associated with strong negative emotions (for example, fear, sadness, anger, depression). Other negative effects of climate change include indecision to have children, threats to family security, scarce opportunities for access to various goods, or the belief that the future is hopeless and doomed to failure (*Hickman et al., 2021*).

According to the relevant literature so far, climate anxiety manifests itself most strongly among 16–30-year-olds (*Van Liere and Dunlap, 1980; Hines et al., 1987; Hawcroft and Milfont, 2010; Milfont, 2012; European Commission, 2017; Clayton and Karasia. 2020*). Intensive examination of this age group is warranted, as they are considered the key figures of the future with their environmentally conscious behaviour. They are expected to occupy decision-making positions and will face important decisions that can be significantly influenced by climate anxiety and concerns about negative ecological

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changes. Beyond the complex global ecological system, it is necessary to examine the diverse causes behind climate anxiety and the actions triggered by it. This article aims to present the results of an international literature review.

2. History and concept of climate anxiety

First, we want to analyze the concept of climate anxiety and then present the definition most researchers accept. Böhm's 2003 article was the first to claim that an increasing proportion of people are feeling frustration, worry, and guilt about the effects of climate change (*Böhm, 2003*). Since the second half of the 2000s, research on the effects of climate change on mental health has gradually increased (*Haines et al., 2006; Berry et al., 2010; Martiello and Giacchi, 2010; Xu et al., 2013*). The term "eco-anxiety" was coined by Albrecht in 2011 (*Albrecht, 2011*).

Research shows that the problem of climate anxiety is mostly determined by the lack of measures to prepare for climate change and its effects on the present and future (*Clayton and Karasia, 2020*). Climate anxiety is defined in the Climate Psychology Handbook as the *"increased emotional, mental or somatic anxiety in response to dangerous changes in the climate system"* (*CPA, 2020*). According to the Cambridge Dictionary, climate anxiety is *"when someone is frightened or very concerned about climate change, changes or damage to Earth's weather systems, and warming that may have been caused by human activity*" (*McIntosh, 2023*).

3. Presentation of major research on climate anxiety

Many factors, such as geographic location, local climatic conditions, and socioeconomic conditions, can influence differences in climate anxiety levels. Climate anxiety often occurs in countries most affected by climate change, which experience severe weather events and disasters. This finding is supported by the fact that the anxiety rate due to high climate change among the young generation living in Portugal is also due to increased forest fires since 2017 (*Hickman et al., 2021*). Baby Boomers describes generations: Born between 1946 and 1964; Generation X: Between 1965 and 1980. Generation Y (Millennials): Born approximately from 1981 to 1996, Generation Z: Born between 1997 and 2012. These regions require immediate attention and resources to mitigate impacts and allay public concerns (*Hickman et al., 2021; Ogunbode et al., 2022*). Figure 1 shows the rate of climate anxiety in percentages in some European countries (*Figure 1*):

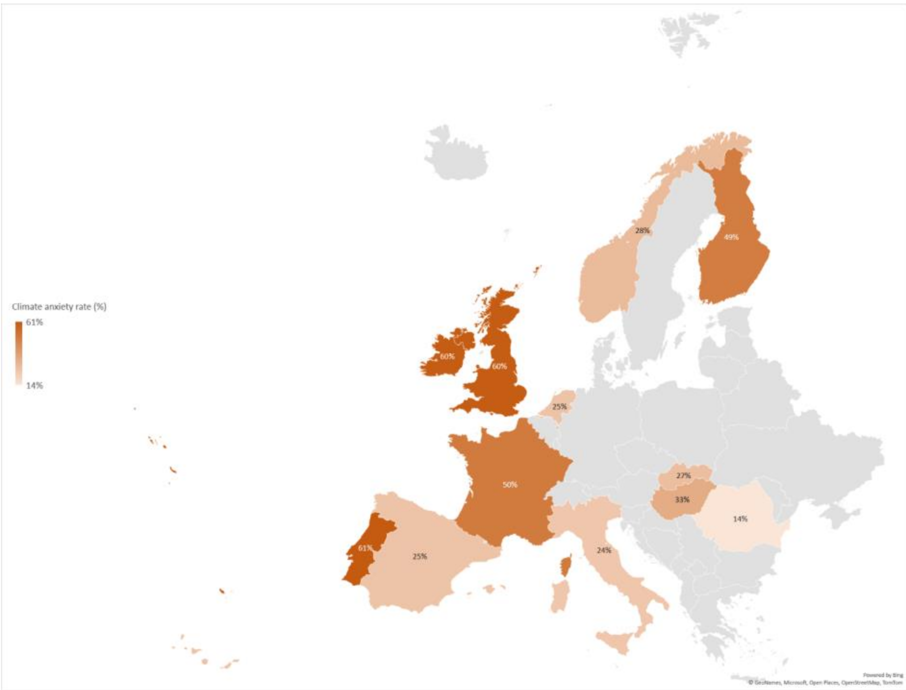

Figure 1: **Results of European countries on climate anxiety within Gen Z.**
Source: Own elaboration on the source of Hickman et al. (2021); UNESCO (2021); Ogunbode et al. (2022), UNICEF (2022)

Based on the data provided in Figure 1, the United Kingdom (60%, N = 1000), Ireland (60%, N = 1200), and Portugal (61%, N = 1000) have the highest levels of climate anxiety among Gen Z, with at least 60% climate anxiety in all three

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countries, compared to 50% in France (N = 1000). According to the results of research conducted in Hungary (33%, *N* = 2007), about a third of respondents and a quarter of respondents in the Netherlands (25%, *N* = 415), Italy (24%, *N* = 294), Spain (25%, *N* = 590), and Slovakia (27%, *N* = 258) felt the strong negative impact of climate change on mental health. Based on Ogunbode et al. (2022), interestingly, in the case of Russia (5%, *N* = 477), the rate of climate anxiety is much lower than in the case of other European countries studied. Russia's extremely low climate anxiety rate likely results from a combination of factors, including the political situation and the ongoing war. For young Russians, current conflicts may become more dominant in their daily lives, so concerns about climate change may fade into the background. Based on this, it can be concluded that the situation regarding the negative mental state caused by climate change is not the same in all countries.

The Climate Anxiety Scale (CAS) was developed by *Clayton and Karasia in 2020*. This scale is based on 13 questions and evaluates respondents' degree of climate anxiety on a 7-point Likert scale ranging from 1 to 7. These questions aim to assess the level of extremely strong emotions in individual and social environments and to identify signs of anxiety affecting everyday life. Clayton and Karasia identified a positive correlation between general and climate anxiety in a US survey using the elaborated scale. However, this anxiety does not necessarily lead to behavioural changes. In addition, they found no clear difference in the degree of climate anxiety between men and women, contrary to most findings in the literature. The researchers also found that environmental attitudes are strongly correlated with behavioural engagement and significantly correlate with climate change experiences. The research suggests that those who identify more strongly with nature respond more strongly to climate change (*Clayton and Karasia, 2020*). Overall, the study concluded that climate change anxiety is common, especially among younger adults, and points out that the specific nature of the worry has a significant impact on an individual's life. At the same time, he showed that although it is closely related to emotional reactions, climate anxiety is not associated with changes in people's behaviour.

Leung and colleagues partnered with Orygen Youth Mental Health to produce the 2022 Mission Australia Youth Survey Report, which surveyed approximately 18,800 Australian youth aged 15 to 19. According to the research, 25.5% of respondents are "very worried" or "extremely worried" about the climate crisis. Among those who expressed concern about climate change, 51% said environmental protection was one of their top concerns. The survey also found that young people who feel concerned about climate change often rate their mental health as "poor or moderate" (*Leung et al., 2022*). These findings highlight that climate concerns have a significant impact on the mental health of young Australians.

Hickman and co-authors published the results of their first global climate anxiety survey in 2021. The research showed that negative emotions among 10,000 young people aged 16 to 25 were strongly correlated with climate change. Survey participants live in Australia, Brazil, Finland, France, India, Nigeria, the Philippines, Portugal, the United Kingdom and the USA. According to the results, most respondents fear climate change (59% are extremely worried). Over 50% reported feeling sad, anxious, angry, helpless, and guilty about the ecological crisis. More than 45% said their feelings about climate change negatively affect their daily lives and actions. Anxiety about climate change is closely related to the perception of a lack of government responses and the resulting sense of betrayal. The researchers concluded that the level of concern about climate change is related to the frequency of negative thoughts. The survey showed that 39.1% of respondents are unsure and prefer not to have children. The findings also show that climate anxiety caused by climate change affects individuals' current and future actions and negatively affects social relationships. 92% of participants are not confident and feel that humanity is doomed. According to them, 55% believe they will have fewer opportunities than their parents, especially regarding job and natural environment prospects. 55% of the participants in the study claimed that the objects, tools, and places they consider important could be destroyed (*Hickman et al., 2021*).

Research conducted by *Stanley et al. (2021)* finds that the COVID-19 crisis has not changed the level of concern about global warming. In contrast, a study by *Noth and Tonzer (2022)* claims that young people's concern about climate change has decreased compared to pre-pandemic times. Several factors can explain this decrease. One factor is that Gen Z tends to live in the present and think short-term, so they are more responsive to current information from the media and their social environment. In addition, air quality improved in several countries during the pandemic, raising hopes for improving the climate (*Noth and Tonzer, 2022*).

Based on a survey conducted by Ogunbode and colleagues in 32 countries, researchers found that GDP positively correlates with the relationship between climate anxiety and environmentally friendly behaviour. However, GDP showed no significant relationship with the link between climate anxiety and mental health nationally. The significant links between

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climate anxiety and environmental activism were mainly confined to relatively wealthy Western countries. In 31 out of 32 countries, climate anxiety was inversely related to mental well-being (*Ogunbode et al., 2022*).

At the same time, it is noticeable that climate anxiety can have not only negative but also positive effects. According to Cunsolo et al., climate anxiety is a feeling that, with appropriate support, can persuade individuals to take proactive, positive actions, including those related to combating climate change (*Cunsolo et al., 2020*). According to Ray, our actions on climate issues stem from our emotions rather than our rational selves. Therefore, the more effectively and quickly we can connect the two ways of thinking, the more effective it can be in protecting the planet from the harmful effects of climate change (*Ray, 2020*).

4. Discussion and conclusion

This article summarized the general findings of a literature review on climate anxiety. We claim that the most important conclusion is to explain the possible role of individual and social actions in addressing the problem.

Considering the actors and roles, it is important to use the theory of subsidiarity, thus taking responsibility and action at the smallest, even individual, level. The study of USC can strengthen the idea that addressing climate anxiety is not only the responsibility of governments and corporations. Individuals and communities also have a role to play in alleviating climate anxiety. Many individual and social actions can address climate change and climate anxiety. For example, cooperation with local authorities can increase the uptake of sustainable modes of transport. It is important to emphasize that decision-making should be dominated by political and financial considerations and real sustainability (*USC Sustainability, 2020*).

At the institutional level, it is also worth making expectations not only for the government, as it is much clearer to identify and address problems at the local government level. However, very importantly related to this is what *Hickman et al. (2021)* write: for young people, government inaction does not only cause moral damage but also violates the satisfaction of basic human needs. Governments need to recognize and understand the causes of climate anxiety and take active action to protect mental health and well-being. A deeper understanding and addressing climate change concerns is critical (*Hickman et al., 2021*).

Climate change concerns decreased during the COVID-19 pandemic (*Noth and Tonzer, 2022*). However, it would be advisable to raise media attention to the adverse effects of climate change, at least at pre-pandemic levels. The reason is that several messages, including encouraging proactive environmental actions, can be conveyed through the media to a wide range of young people belonging to Generation Z. Although fear drives climate action in the short term, belief in positive change is the most motivating factor in the long term. The faith and hope attributed to success generate additional activities that improve the state of the planet and reduce feelings of climate anxiety regarding the mental state of young people (Kleres-Wettergren, 2017). Other solutions to support long-term sustainability include active, dialogue-based science education, developing critical thinking skills, and deepening shared visions of a sustainable future (*Kelly et al., 2022*).

These findings from the literature confirm the special role of the media and education in addressing this problem. These two "social activities" cannot be ignored since, as stated at the beginning of this article, climate anxiety is the strongest among 30-year-olds. This age group has a strong presence in the education system (teachers, parents), and social media use is also a feature of individuals in this age group. Within media use, communication, and information, the reliability of information is a key issue, which is why we deliver information to Generation Z.

We believe that the role of education is unquestionable, be it in the 16–30 age group at secondary or higher education level, but also in the world of adult education or post-graduate training, where there is a place for the transmission and reception of relevant and reliable information. The openness of individuals to the subject, both in their roles as teachers and as students, is a decisive factor.

In addition to roles, defining activities is also an important task. We think climate anxiety is a feeling that, with appropriate support, can persuade individuals to take proactive, positive actions that can work. However, providing appropriate information and communicating about it is also important. Overcoming anxiety can motivate, but reliable communication of the positive environmental effects is essential.

Comprehensive change can only happen if people understand that climate change requires an immediate response, and action must be taken at the individual level. Global thinking and local action have the potential to reduce climate anxiety.

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Realisation of Low Temperature Combustion in an Unmodified Diesel Engine

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Abstract

Heavy-duty diesel engines are an essential part of road transportation. Since viable alternatives are not expected in the short and medium term, the problematic emission characteristics of compression ignition engines must be addressed. Low-temperature combustion (LTC) is an alternative combustion method for compression ignition engines that allows low particulate matter and nitrogen oxide emissions while improving efficiency. To overcome the difficulties of market introduction, the realisation of such alternative combustion methods should come with marginal engine modifications. Thus, this work investigates a possible realisation of LTC in an unmodified diesel engine. LTC methods were studied with and without injection strategy modifications to provide sufficient recommendations for other researchers. It was concluded that techniques requiring early direct injection, such as homogeneous charge compression ignition (HCCI), necessitate a narrow cone angle injector to reduce wall impingement. It was also determined that modulated kinetics (MK) type LTC can be easily achieved by applying a conventional injection strategy and high amounts of cooled exhaust gas recirculation. The realised MK combustion resulted in an enhanced NO_x-PM trade-off and a lower peak pressure rise rate than normal operation.

Keywords

Low-temperature combustion, Modulated Kinetics, Homogeneous Charge Compression Ignition, Low-Pressure Exhaust Gas Recirculation

1. Introduction

Among the many concerns about future mobility, the environmental aspects of road transport are one of the most significant (*Zöldy, 2009*). As a reaction to global challenges, the European Union (EU) set many ambitious goals for the European Green Deal (*Fetting, 2020*). Until 2050, the EU aims to become climate neutral; thus, many policies, such as the new 95 g/km CO_2 emission limit, were formulated. Moreover, the Ambient Air Quality Directive (*EP, 2008*) aims to achieve zero air pollution by 2050. Regarding road vehicles, the new Euro 7 norm (*EP, 2023*) is essential to achieving this goal. Electrification is the most discussed topic from the wide variety of alternative technologies. Due to its many advantages, it can be a proper solution for passenger cars; however, there are some transportation sectors where this technology cannot be applied (*Koller et al., 2022*). Besides the slow charging time and the lack of infrastructure, the main problem with batteries is their low energy density. The latest EU forecasts expect 500 Wh/kg batteries by 2030 (*Edström, 2020*). This equals 1.8 MJ/kg of energy density, much higher than current vehicle batteries' energy densities. However, liquid hydrocarbons have lower heating values (LHVs), well above 40 MJ/kg (*Manuel and Chivanga Barros, 2023*). Thus, this significant difference prevents the use of batteries in applications that require high energy density on-board energy storage. Heavy-duty vehicles for road transport are among these critical applications. Thus, alternatives have to be identified.

One of the most promising alternatives for heavy-duty vehicles is the application of carbon-neutral advanced fuels (*Tóth et al., 2020*). By applying these, the well-to-wheel CO_2 emission can be minimised (*Virt et al., 2022*). Advanced fuels can also positively affect pollutant emissions; however, additional engine improvements are necessary to reduce air pollution further in internal combustion engines (*Zöldy, 2007; Zöldy and Vass, 2018*). The most critical emissions from heavy-duty diesel engines are nitrogen oxides (NO_x) and particulate matter (PM). NO_x is mainly generated through the Zeldovich mechanism (*Zeldovich, 1946*) due to the high oxygen concentration and temperature during combustion. The PM emission can be attributed to the inhomogeneity of the fuel mixture. Solid combustion products are formed in local rich zones, and soot is formed through agglomeration (*Heywood, 1988*). The simultaneous reduction of these compounds is impossible in conventional diesel engines due to a trade-off between them.

Low-temperature combustion (LTC) can overcome this issue with a new combustion technology that lowers combustion temperature (*Agarwal et al., 2017*). LTC applies a homogeneous lean mixture, high residual gas, and compression ignition to improve engine characteristics (*Krishnamoorthi et al., 2019*). The lean homogeneous mixture ensures low PM emission, while the high heat capacity of residual gases results in lower combustion temperature, lowering NO_x emission. The compression ignition provides high brake thermal efficiency. In addition, an LTC engine is also quality-controlled; thus, the lack of a throttle valve reduces engine losses (*Singh et al., 2018*). The low exhaust gas temperature also contributes to higher efficiency since the heat loss is reduced—the autoignition of the homogeneous charge results in volumetric combustion. However, the residual gases slow the combustion; thus, the peak pressure rise rate (dp_{max}) can be kept in an acceptable range. The amount of residual gas can be increased by applying internal or external exhaust gas recirculation (EGR). Usually, external EGR is preferable since the recirculated exhaust gases can be cooled down before reintroduction (*Nyerges and Zöldy, 2020*).

The advantages of the previously described LTC process make this technology promising for commercial diesel engines. However, some serious demerits make its application challenging. First, the low temperature can be problematic since it may lead to incomplete combustion. Therefore, LTC engines can have higher CO and HC emissions. Other unregulated emissions, such as formaldehyde or polyaromatic hydrocarbons (PAHs), can also increase.

Moreover, the lower exhaust gas temperature reduces the efficiency of conventional catalytic converters; therefore, new after-treatment systems may be necessary. The harder cold start of LTC engines can further increase these emissions. Besides low temperatures, the compression ignition of the homogeneous charge generates challenges. Since the homogeneous mixture is autoignited, the start of combustion (SoC) can only be controlled through indirect parameters, making combustion control difficult. The EGR sufficiently slows the reaction kinetics; however, the homogeneous charge still results in a rapid heat release, and the duration of combustion (DoC) is short. This short DoC leads to worsening oxidation due to the shorter combustion times. Also, rapid ignition means that higher loads must be avoided because the pressure rise rate can be unacceptably high. This limits the operating range of the engine. To prevent high-pressure rise rates, extremely lean mixtures are used. For low loads, the mixture can be so lean that cyclic variations increase or even misfire can occur. Thus, the operating range has a lower limit. Finally, applying homogeneous mixtures can also lead to severe wall wetting if early direct injection (DI) is used to formulate the charge. This increases emissions, decreases efficiency, and leads to oil dilution.

Several different LTC technologies are described in the literature. Homogeneous charge compression ignition (HCCI) is one of the most commonly investigated methods (*Duan et al., 2021*). It achieves LTC by following the exact principles described previously. Therefore, it provides good engine behaviour in a specific operating range but exhibits all the described disadvantages outside of this range. Many other LTC techniques exist to solve the problems in a wider operating range. These do not follow the LTC principles precisely; thus, they achieve a compromise between the benefits of LTC and the increased operating range. This paper focuses on unmodified engines; therefore, LTC methods without specific modifications must be identified. Some technologies require extreme modifications, such as reactivity-controlled compression ignition (RCCI) that slows combustion by stratifying mixture reactivity with a dual fuel system (*Elkelawy et al., 2022*).

Another example is thermally stratified compression ignition (TSCI), which achieves thermal stratification through direct water injection (*Rahimi Boldaji et al., 2018*). These complex modifications may lead to good combustion characteristics, although smaller changes can also be enough. Mixture homogeneity is one of the factors that creates the most benefits and demerits. Thus, a compromise can be achieved by reducing homogeneity. Premixed charge compression ignition (PCCI) and partially premixed compression ignition (PPCI) are examples of this approach (Hoang, 2020). They apply an injection strategy that provides enough time for a premixed charge, so the homogeneity is higher compared to normal operation; however, the charge is not as homogeneous as in the case of HCCI. Modulated kinetics (MK) also follows this approach (*Lee and Huh, 2014*). Still, it can be considered an extreme example since it applies injection timings similar to conventional

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diesel engines or even later timings in some cases. Extremely high EGR rates can achieve the premixed charge to prolong the ignition delay (ID) so much that the fuel has time to mix with the air. Some essential factors can help achieve good MK combustion. The EGR has to be cooled, and the combustion chamber's geometry should provide a high swirl for proper mixing. However, MK is only suitable for low loads, as high amounts of fuel cannot be properly mixed.

This work aims to achieve LTC in an unmodified commercial diesel engine to provide recommendations and best practices for researchers to achieve LTC operation more easily. The case study investigated the possible realisation of LTC with and without injection strategy modification. The LTC is achieved by applying cooled low-pressure EGR.

2. Materials and Methods

2.1. Experimental Apparatus

The experiment was conducted on a Cummins ISBe 170 30 turbocharged, medium-duty commercial diesel engine, which had been used in numerous previous studies (*Nyerges and Zöldy, 2023; Virt et al., 2023; Virt et al., 2024*). This engine features a common-rail injection system, an intercooler, and a high-pressure (HP) and low-pressure (LP) EGR system. For the experiment, the engine was mounted on an engine dynamometer. Temperature and pressure readings were taken at the intake side both before and after the compressor, as well as after the intercooler. On the exhaust side, measurements were taken before and after the turbine and at the exhaust outlet. Fuel consumption was recorded using an AI 2000 gravimetric device.

Table 1. Cummins ISBe 170 30 main parameters

Displacement	3922 cm^3
Bore	102 mm
Stroke	120 mm
Compression Ratio	17.3
Rated Effective Power	125 kW

The HP- and LP-EGR valves and the exhaust brakes adjusted the EGR rate. Only the LP EGR valve and an exhaust brake were utilised during the measurements. The valves were controlled via CAN communication using a dSpace MicroAutoBox DS1401/1505/1506, and sensor data were also transmitted via CAN. Combustion analysis was conducted using an AVL indicating system. Cylinder pressure was measured with an AVL GH13P piezoelectric sensor connected to the glow plug seat with a linearity of ±0.3% FSO. The crankshaft position was determined with an AVL 365C crank angle encoder with 0.1°CA resolution. The indicating data were processed with an AVL 612 Indi-Smart, an 8-channel multipurpose indicating device with charge amplifiers for the piezoelectric sensors. AVL IndiCom was used to process the combustion data, and an additional Matlab/Simulink model was used to record emission and fuel consumption data. Oxygen and NOx concentrations were measured with a UniNOx-Sensor with an accuracy of 10 ppm. Exhaust gas opacity was assessed using an AVL 439 opacimeter with 0.1% sensitivity. Emissions were not treated with catalysts or a diesel particulate filter.

The injection could be modified in all cylinders. A dSpace RapidPro Power Unit with two PS-DINJ 2/1 modules drove the injectors. A dSpace MicroAutobox DS1401/1505/1506 controlled the start of the injection, while an Arduino UNO Rev3 controlled the duration of the injections. The desired engine speed could be set with a potentiometer, and a PID controller running on the Arduino set the necessary dose.

2.2. Calculation methods

Several parameters have to be calculated. Some parameters are based on the engine's normal power:

$$P_{norm} = P_{eff} \cdot \frac{p_0 - \phi_0 \cdot p_{g0}}{p_{amb} - \phi_{amb} \cdot p_{g,amb}} \cdot \sqrt{\frac{t_{amb}+273}{t_0+273}}, \quad (1)$$

where P_{eff} is the effective power, p_{amb}, t_{amb}, ϕ_{amb} are the ambient pressure, temperature and humidity, p_0, t_0, ϕ_0 are the pressure, temperature and humidity under normal conditions, and p_g is the vapour pressure of water. The first calculated parameter is the brake-specific fuel consumption (BSFC) that is required to calculate brake thermal efficiency (BTE) later:

$$BSFC = \frac{\dot{m}_{fuel}}{P_{norm}}, \quad (2)$$

where $\dot{m}_{fuel}$ is the fuel mass flow. Then, the BTE can be derived:

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$$BTE = \frac{1}{BSFC \cdot LHV}, \quad (3)$$

where LHV is the lower heating value of the mixture.

The combustion-related parameters are calculated from the cylinder pressure. The combustion temperature is derived from the ideal gas law. Note that this simple assumption is only enough to compare the trends of the investigated combustions. The heat release rate (HRR) is calculated from the First Law of Thermodynamics (*Heywood, 1988*):

$$\frac{dQ_b}{d_\phi} = \frac{\kappa p}{\kappa - 1} \cdot \frac{dV}{d_\phi} + \frac{V}{\kappa - 1} \cdot \frac{dp}{d\phi} - \frac{dQ_W}{d_\phi}, \quad (4)$$

where Q_b is released heat, κ is the adiabatic gas constant of air, p is the pressure in the combustion chamber, V is the volume of the combustion chamber, Q_w is the heat loss, and ϕ is the crank angle. The heat loss was neglected during our calculations. The start of combustion (SoC) is the crank angle where 5% of the heat is released. The 90% heat release marks the end of combustion. The duration of combustion (DoC) is the difference between the two previous crank angle values.

3. Results and Discussion

3.1. LTC with Modified Injection Strategy

First, the possibility of LTC realisation is investigated with a modified injection strategy. HCCI, PCCI, and PPCI require earlier DI to achieve higher degrees of homogeneity and a high EGR rate. The main difference between these technologies is the degree of homogeneity. HCCI has near-perfect homogeneity, while PPCI only applies a partially premixed charge. The homogeneity can be controlled with injection timing. Thus, single injections with six different start of injection (SoI) values between 300 and 350 °CA were investigated. The EGR is another crucial factor in LTC. The LP-EGR of our test system can be cooled; thus, it was preferred over the HP-EGR system. Based on our previous experiences, intake oxygen concentrations were kept between 13% and 14% with the LP-EGR and an exhaust brake. The investigated operating point was selected to be 1250 rpm with 50 Nm. This provides low load conditions, thus making the realisation of LTC easier.

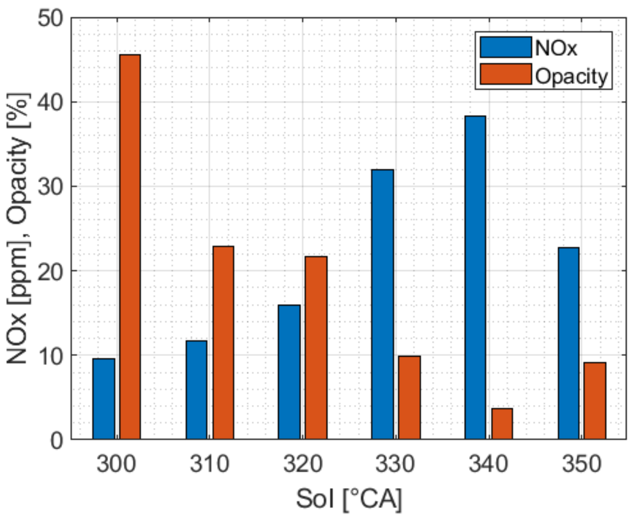

Figure 1. NO_x emission and opacity at different injection timings.

The main goal of LTC is to improve the NO_x–PM trade-off. Therefore, Figure 1 presents NO_x emission and exhaust opacity at different injection timings. As expected, NO_x emission is low in all cases due to the high amount of EGR used. By changing the SoI, a relatively small change of around 30 ppm occurred. This may be attributed to the change in combustion temperature. It is also discernible that the trade-off is present between NO_x and soot generation. At the latter injections, the opacity is lower, while the values for NO_x emission are higher.

Conversely, earlier injections lead to slightly lower NO_x emissions and much higher opacity. LTC should not produce higher opacity for early SoIs due to the higher homogeneity. Thus, this is a clear sign of increased wall wetting. Our test engine has regular injectors because the aim is to achieve LTC without applying any hardware modifications. According to the literature, this result was expected since narrow cone angle injectors must be applied to avoid high levels of wall impingement. Another sign of extreme wall wetting is the increased fuel consumption. The engine required 1.0 g/s of fuel

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to maintain the operating point with 350°CA SoI, while the consumption increased to 1.6 g/s when 300°CA SoI was applied. Overall, it can be concluded that LTC with early DI cannot be realised without narrow cone angle injectors.

3.2. LTC with Conventional Injection Strategy

LTC may be achieved without the modification of the injection strategy. The previously described MK combustion can theoretically be achieved by applying extremely high rates of cooled EGR. However, the geometry of the combustion chamber can also be critical since a high swirl is required for proper mixing. A previous experiment investigated four dual-loop EGR modes on this test engine (Nyerges and Zöldy, 2023). The study examined the effects of the different EGR valves and exhaust brakes. The experiments found that LP-EGR can lead to a drop in NO_x and PM emissions. This suggests that LTC might have happened in that experiment. Based on the findings, the combustion and emission of the engine is investigated at 1250 rpm and 50 Nm. The EGR rate is increased with the LP-EGR valve and an exhaust brake to reproduce and analyse the phenomenon in detail.

Figure 2 presents the measured NO_x emission and exhaust opacity regarding the intake oxygen concentration. The engine exhibits normal EGR behaviour up to an oxygen concentration of 12%. Increasing the EGR ratio (decreasing oxygen levels) causes the NOx emission to drop and the opacity to rise due to the trade-off. However, the engine behaviour changes if oxygen intake is below 12%. The NO_x continues to drop, but now the opacity also decreases. Around 9.5% of the intake oxygen levels are high, and the opacity is not much higher than in the case of normal operation without EGR, while the NO_x emission is nearly eliminated. This is a much better compromise between the emissions than the original. Thus, it can be assumed that MK combustion was achieved when the intake of oxygen levels reached 9.5%.

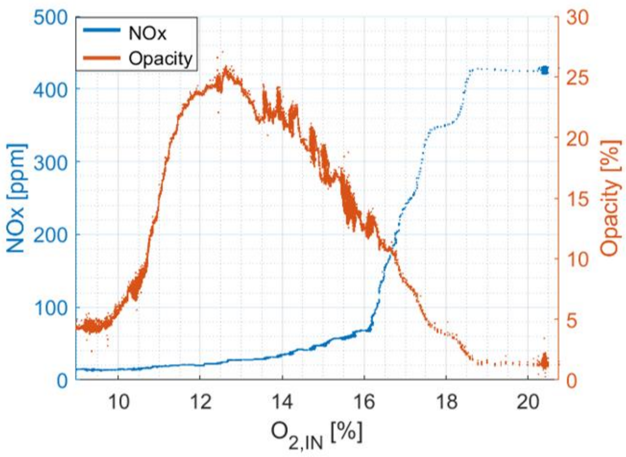

Figure 2. NO_x emission and opacity with conventional injection strategy and increasing LP-EGR levels.

Now, further analysis of this possible MK combustion is necessary. Figure 3 demonstrates the heat release rates in normal operation (without EGR) and MK operation. The MK was achieved at 1250 rpm and 50 Nm by increasing the LP-EGR levels with the LP-EGR valve and the exhaust brake until the intake oxygen dropped to 9.5%. The engine ECU applied a pre-injection between 339 and 342 °CA and a main injection between 348 and 354 °CA in normal and MK operations. It is discernible that normal operation involves conventional diesel combustion. After the pre-injection, a small heat drop occurs due to the fuel's heat dissipation. Then, around the start of the main injection, the combustion also starts with a short premixed phase, where the dose of pre-injection burns mainly. The ignition delay between the start of the main injection and SoC is small; therefore, the main dose burns in the slow diffusion phase. The MK operation mode exhibits an entirely different behaviour. First, the combustion is highly delayed by the EGR. This prolonged the ignition delay so much that the main dose could achieve premixed conditions. Therefore, the heat release rate is nearly symmetrical. The symmetrical shape signifies LTC combustion (*Agarwal et al., 2017*). Before SoC, a small heat release peak can also be observed. This is the low-temperature heat release (LTHR) or cool flame phase. The ignition has not started yet; only reactions with small activation energy have occurred. This is another typical sign of diesel fuel's LTC combustion. A separate mixing-controlled diffusion phase cannot be identified in the diagram. The final slower combustion part can be attributed to the remaining

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reactions with slow reaction kinetics. Despite the autoignition of the premixed charge, the DoC is relatively long due to the high EGR rate; thus, the mechanical load of the engine is expected to be low.

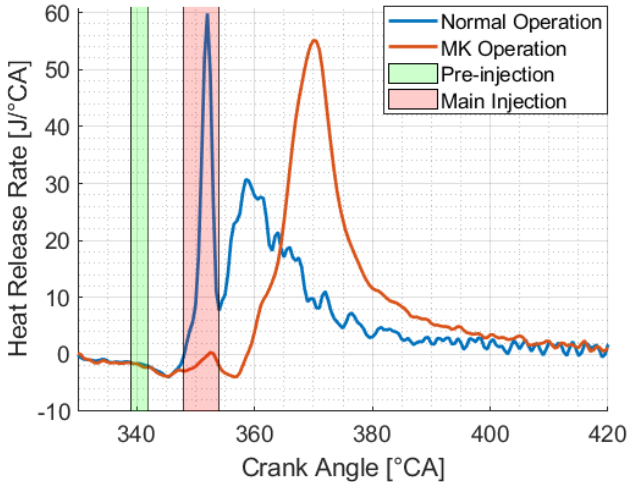

Figure 3. Heat release rates of normal and MK operation modes at 1250 rpm and 50 Nm.

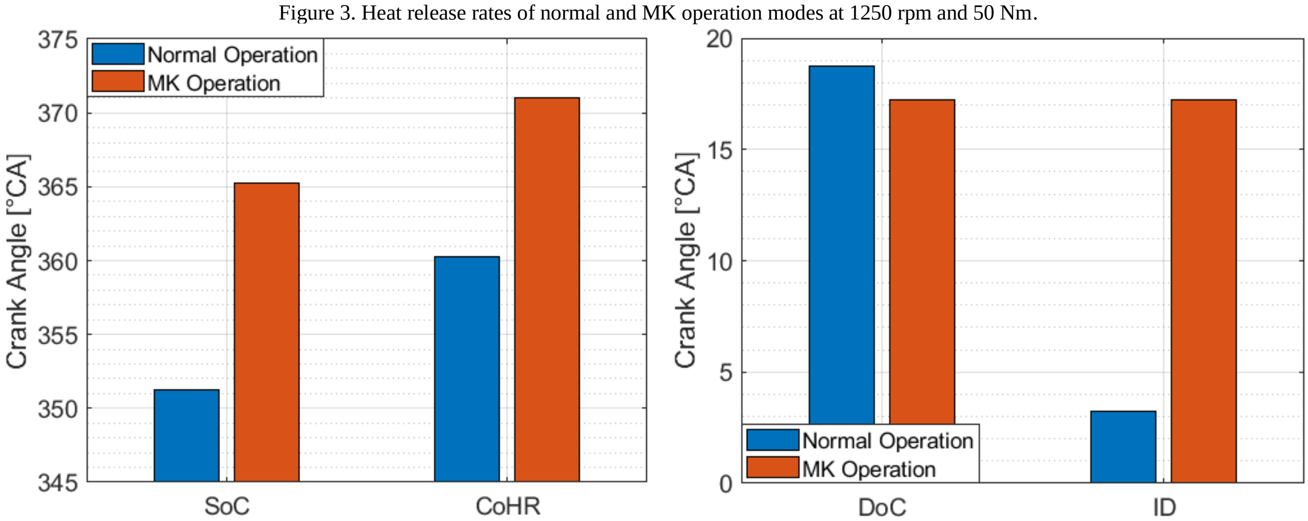

Figure 4. SoC, CoHR, DoC, and ID of normal and MK operation modes at 1250 rpm and 50 Nm.

The SoC and the centre of heat release (CoHR) are important combustion parameters that affect brake thermal efficiency. Figure 4 presents these values for normal and MK operation modes. In normal operation, the combustion starts shortly after the main injection, while in the case of MK mode, it starts after the top dead centre (TDC). The reason for the delay is the high amount of cooled LP-EGR. The CoHR is also retarded due to the latter SoC. The BTE is the highest when the CoHR is close to TDC. Therefore, the normal operation's CoHR is good, but the MK's late CoHR may lead to loss of work since the charge has less time to produce work during the power stroke. This can reduce BTE.

The DoC and the ID are important combustion parameters that affect combustion quality. Figure 4 also presents these values for the two operation modes. A shorter DoC can lead to higher BTE, while it can also increase the pressure rise rate. During LTC, the autoignition of the homogeneous charge provides a hazard for the engine due to the rapid combustion. The slowing effect of the residual gases makes the LTC feasible. Comparing the DoC of the MK combustion with the normal one, it can be observed that only a small drop arose due to the homogeneity. The EGR rate was extremely high; thus, the combustion could be prolonged well. The other effect of EGR is the delay of SoC. The ID from the start of the main injection increased by 14°CA, which is a significant change. This longer ID provides sufficient time for the fuel of the main dose to form a premixed charge with the air.

Peak pressure rise rate, brake thermal efficiency, and peak combustion temperature are important parameters for properly evaluating MK combustion. These are summarised in Table 2. Despite the decrease in DoC, MK's peak pressure rise rate is much smaller than normal. During normal operation, this peak occurs during the premixed phase, characterised by short but

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rapid combustion. In the case of MK combustion, the whole charge is premixed, but the EGR slows reaction kinetics. Therefore, the rate of pressure rise becomes small.

Regarding the BTE, it can be noted that the low engine load led to small efficiencies. However, the MK exhibits an even smaller BTE. The main reason for this drop can be the retarded CoHR that resulted in loss of work. The estimated peak combustion temperature is also low due to the low load. The applied high levels of EGR decreased this temperature by nearly 100 K. This can contribute to smaller NOx emissions.

Table 2. Peak pressure rise rate, brake thermal efficiency, and peak combustion temperature at the operation modes

	Normal operation	MK operation
dp_{max} [%]	5.82	1.48
BTE [%]	19.96	16.35
T_{max} [K]	1482.8	1381.7

Overall, the investigation proved that LTC could happen by applying extremely high rates of cooled LP-EGR. The method provides similarities to the MK combustion technology described in the literature. Thus, it can be concluded that the observed phenomenon is an MK-type LTC.

4. Conclusion

This paper investigated the possibility of realising LTC in an unmodified commercial diesel engine. Two approaches were studied: LTC with and without injection strategy modification. The LP-EGR was utilised for all cases because it can be cooled better. It was found that forming a homogeneous mixture with early direct injection is impossible due to the increasing wall wetting. According to the literature, this problem can be solved by applying a narrow cone angle injector. Without injection strategy modification, the realisation of MK-type LTC was possible. The applied high LP-EGR rates resulted in a prolonged ignition delay, making forming a premixed charge possible. This enabled low soot generation, while the high EGR rate provided low NO_x emission; thus, the NO_x-PM trade-off could be enhanced. However, the brake thermal efficiency decreased by around 3.5% due to the retarded centre of heat release that led to the loss of work. It can be concluded that the MK may be a possible solution to improve the emission values of commercial diesel engines, although other techniques, such as applying oxygenated e-fuel, could be an excellent supplementary solution.

Acknowledgement

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Optimising Air Traffic Management in Europe by the introduction of the Single European Sky

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Abstract

Europe´s airspace is facing an arduous situation due to its congestion, which leads to multiple delays and inefficient flights. Introducing the Single European Sky Air Traffic Management (SESAR) initiative will conquer a transformative shift in Europe´s Air Traffic Management (ATM), achieving more optimised and sustainable routes throughout the continent. Therefore, through the successful implementation of the SESAR initiative, we will enhance the performance of Europe´s ATMs in capacity, safety, efficiency, and sustainability. This paper evaluates Europe´s current airspace and highlights the positive impacts of the initiative in the different areas of improvement. Utilising current data provided by the airlines, qualitative methods are applied to prove the effect that SESAR will achieve on different routes. The research results demonstrate how introducing the SESAR will reduce flight distance, fuel consumption, and emissions. In conclusion, this research emphasises the significance of implementing the SESAR to update air traffic control throughout Europe. The aviation industry is experiencing a modernisation that is expected to result in lower operating costs, fewer delays, and a reduction in the environmental impact of their flights.

Keywords

Air traffic Management (ATM), airspace, SESAR, efficiency, sustainability

1. Introduction

As the number of flights continues to rise in Europe, the delays they experience likewise increase. In addition to delays, the congestion in Europe´s airspace causes problems related to capacity, efficiency, safety and environmental issues. All of these could be improved and even eradicated with the implementation of the Single European Sky Air Traffic Management (SESAR). Europe´s air traffic management is facing a complicated situation due to its fragmentation and heterogeneity, which leads to congestion problems where demand mismatches capacity.

According to Eurocontrol, the intergovernmental organisation in charge of air navigation security in Europe, flights across the continent are, on average, 42 km longer than the minimal route, costing 4 billion euros per year. Furthermore, the demand for European flights is increasing at a rate of 4.5% per year, a demand that the current capacity cannot support, resulting in a 3.3% increase in aeroplane movements (*Rosenow & Fricke, 2019*). In addition, Europe´s airspace experiences a lack of coordination since there is no common Air Traffic Control (ATC) system, with 22 different systems operating through 44 centres (*Luftraumntzer, 1989*). This all translates into a greater strain on Europe´s airspace infrastructure, which in turn causes delays and rises in operating costs, and presents difficulties for air control systems and airlines.

However, with the introduction of the Single European Sky initiative, flights will follow more direct routes, resulting in a tenfold increase in safety, a tripling of airspace capacity, a 50% reduction of ATM costs, and a 10% decrease in the environmental impact of aviation. The direct routing of the flight can be achieved by introducing the Free Route Airspace (FRA), allowing aircraft to fly directly from one destination to another following an orthodromic or loxodromic route at the highest flight levels. This study underpins this expectation through the example of the Madrid–Budapest route.

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The bibliometric network analysis below shows (*Figure 1*) 8 different concepts related to the research topic of the optimisation of air traffic management in Europe. Four of these eight concepts are important: air transport, aviation, air traffic control, and air traffic management.

Air transport is crucial for optimising air traffic management, as all the airlines' connectivity and competitiveness influence traffic. In addition, it is also important to understand how different airports operate, the types of traffic they handle, and whether they function as a point-to-point or a hub-and-spoke system. Undoubtedly, to have air transport, we need aviation procedures that include all the safety regulations and procedures and security. Safety and security in aviation serve distinct but interconnected purposes. Safety focuses on unintentional threats and risks associated with aviation activities. It aims to reduce and control risks related to aircraft operations, ensuring the well-being of passengers, crew, and assets. Safety measures address accidents, technical failures, and human errors. Security, on the other hand, deals with deliberate threats. It safeguards civil aviation against unlawful interference, such as terrorism, hijacking, or sabotage. Security measures aim to prevent intentional harm to planes, passengers, and airport facilities. In summary, safety prevents accidents, while security protects against intentional harm. Both are critical for a robust and reliable aviation system.

Apart from the four major topics, it is also important to mention sustainability and climate change. Air traffic involves various aspects of energetic and renewable efficiencies in different alliances and severely affects air pollution and ozone levels. In the present study, we will mention how conflict resolution can be made more efficient with the different data or how artificial intelligence can be considered to improve efficiency and safety in aviation.

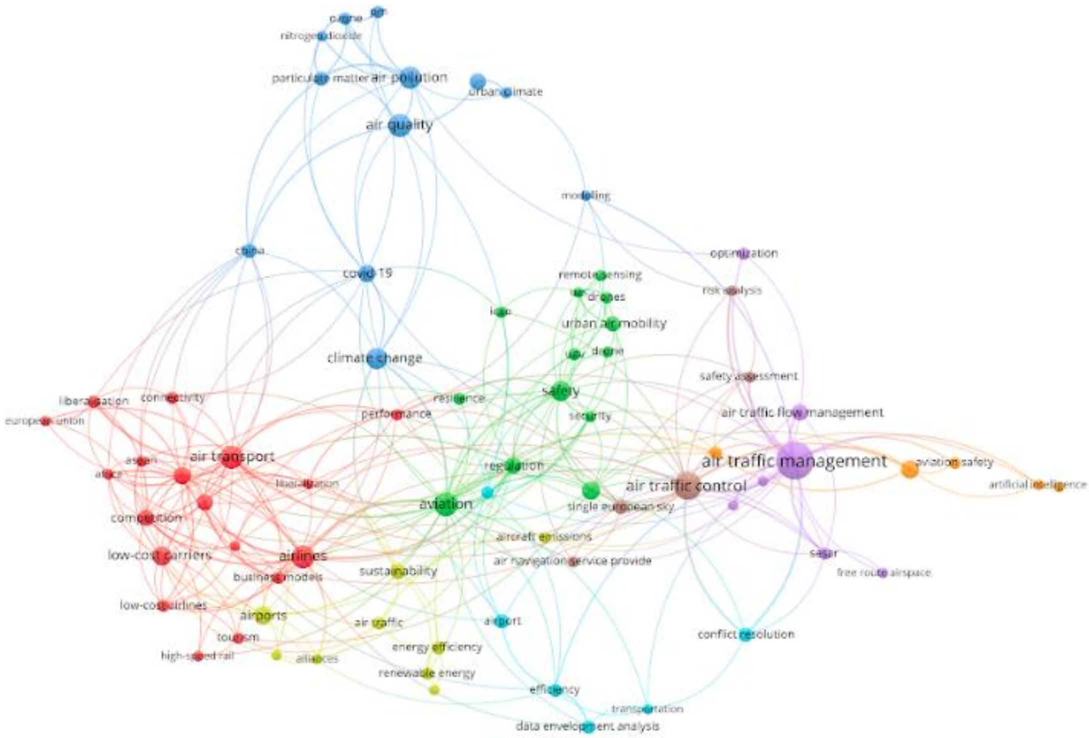

Figure 1: **Bibliometric network analysis for the concept of air traffic management optimisation**

Therefore, this paper demonstrates how implementing the SESAR initiative through European airspace will reduce operational costs and emissions while increasing capacity and efficiency. Throughout this article, we will explain the calculation methodology and present their results. These results are analysed, and then the article is concluded.

2. Data and methods

To prove how the introduction of the SESAR will improve European airspace efficiency, the Madrid–Budapest route is analysed using an orthodromic and a loxodromic route. Throughout the en-route phase, the concept of the Free Route Airspace is utilised instead of flying from one waypoint to another, which seems inefficient. However, to maintain the safety of the flight, the Standard Instrument Departure (SID - is a predefined route that guides an aircraft from takeoff to the en-route phase. It ensures safe and efficient departure by specifying specific routings, altitudes, and speed restrictions), the

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Standard Arrival Route (STAR - guide aircraft from the en-route phase to an initial approach fix).and the final approach procedures (The final approach is the last segment of an instrument approach procedure. It begins at the final approach fix and leads to the runway threshold) are maintained. In this article, these segments will be investigated separately.

The orthodromic route is the shortest distance between two points along a great circle. The equations below calculate the distance between Madrid and Budapest using the orthodromic route. For visualisation, see Figure 2:

$$\sin(\lambda_1 - \lambda_0) = tg(\varphi)tg(\theta) \quad (1)$$

$$sen(\theta) = \frac{sen(\theta\ 0)}{\cos(\varphi)} \quad (2)$$

$$sen(s) = \frac{sen(\varphi)}{\cos(\theta\ 0)} \quad (3)$$

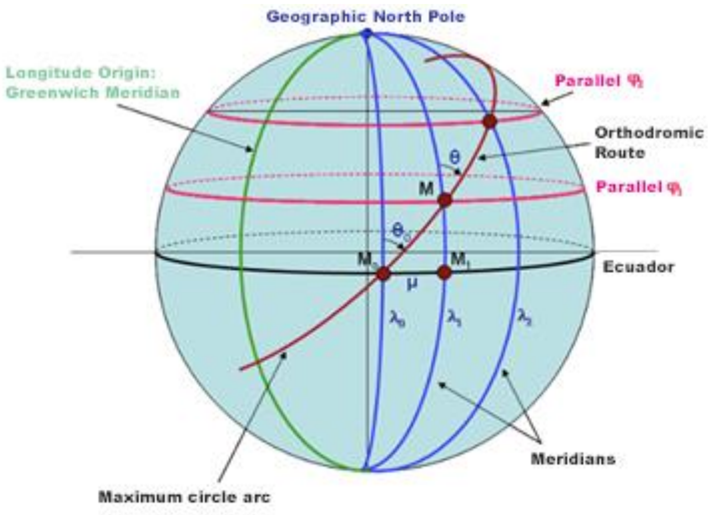

Figure 2: **Orthodromic Route**
Source: Pérez Sanz et al., 2013

Therefore, we will pursue the following procedure to determine the distance between these two airports using the orthodromic route.

To start, we first need the generalised coordinates we see below (*Coordinates Converter, 2024*):

- Adolfo Suarez Madrid Barajas (MAD: 40, 498332º, -3, 567598º)
- Budapest Airport Ferenc Liszt (BUD: 47,435273º, 19,253511º)

Accordingly, the longitude and latitude of each airport will be:

- MAD (φ_1 =40, 498332º, λ_1 = -3,567598º)
- BUD (φ_2 =47, 435273º, λ_2 = 19, 253511º)

Using the first expression from above (Eq. 1), we obtain that λ_0 has the value of -50,1694416, which makes sense, as it is the point where the route crosses the equator. This will be on the other side of the equator, on the negative side, as shown in Figure 3.

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If we divide the earth into quadrants, we can check if Madrid and Budapest are in the same quadrant if we subtract the coordinate value of the point that crosses the equator from the coordinate value of their longitude, which is less than 90.

- MAD $|\lambda_1 - \lambda_0| < 90$
- BUD $|\lambda_2 - \lambda_0| < 90$

As we expected from Figure 3, Madrid and Budapest are in the same quadrant. Therefore, we calculate their distance to the point that crosses the equator with equation 1. Thus, we obtain θ_0Then, using Equation 3, we get both distances s_1 and s_2, with the values of 58,5025475º and 75,2408343º, respectively. Finally, as shown in Figure 3, we calculate the result of s_2 minus s_1, getting 16,738382869º. This distance in Nautic miles is 1004,29 NM, and in kilometres, it is **1859,94 km**.

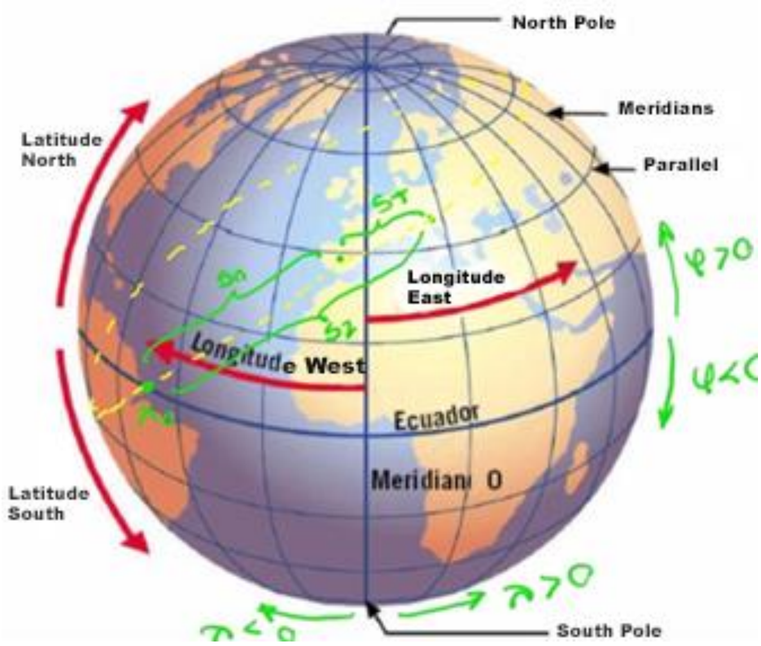

Figure 3: **Orthodromic Route**
Own compilation based on (Domínguez, 2014)

Once having calculated the distance using the orthodromic route, we will continue by calculating the loxodromic route. This route follows a rhumb line, which cuts the different meridians at the same angle, consequently maintaining a constant direction. To calculate this route, we will use the equations 4–7 below, explained by the trigonometric concepts in Figure 4.

$$ds_p = ds * sen(\theta) = r * d\lambda \quad (4)$$
$$ds_m = ds * cos(\theta) = R * d\varphi \quad (5)$$
$$d\lambda * \cos(\varphi) = tg(\theta) * d\varphi \quad (6)$$
$$\lambda - \lambda_0 = tg(\theta_0) * \ln(tg(\frac{\pi}{4} + \frac{\varphi}{2}) \quad (7)$$

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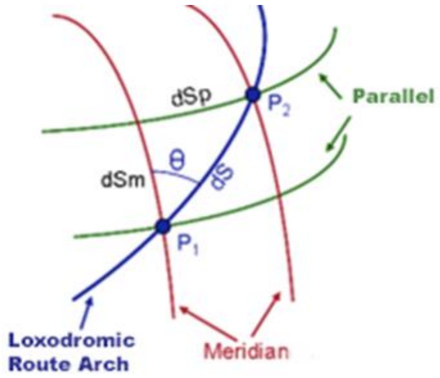

Figure 4: **Relations in the loxodromic route**
Source: Pérez Sanz et al., 2013

Logically, we start calculating the loxodromic route with the generalised coordinates, which are the same ones as in the orthodromic route.

- MAD (φ_1 =40, 498332º, λ_1 = -3,567598º)
- BUD (φ_2 =47, 435273º, λ_2 = 19, 253511º)

Accordingly, using the fourth equation, we get the direction of the route, θ_0, which has a value of -67,0681045º, se as Budapest is located to the northeast of Madrid. After calculating the direction, we will use Equation 1 of the orthodromic route to get λ_0, which will be -101,2948108º. This is a larger number than in the orthodromic route, as we must maintain the direction of the route. Lastly, we will calculate the distances s_1 and s_2 as the final distance.

$s = s_2 - s_1$= 7304,538818-6236,3220337= 1068,22 NM= **1978,34 km**

This is the distance between the two airports following a loxodromic route, which is more than 100 km longer than the length of the orthodromic route. However, if we consider the SID and the STAR as mentioned, we will follow the same procedure but calculate the distance with the coordinates of the SID's last point and the STAR's first point. Then, we will add the distance mentioned in the aeronautic charts taken from EUROCONTROL, separating the runway and the waypoint the aircraft will follow at departure and arrival. In this example, we used departure from PINAR and arrival from ULZAK and ATICO.

3. Results and discussion

Taking into account the estimations mentioned above and the distances between the waypoints that we obtain from the charts displayed in Figures 5, 6 and 7, i.e. the distances of the orthodromic and loxodromic route are the following:

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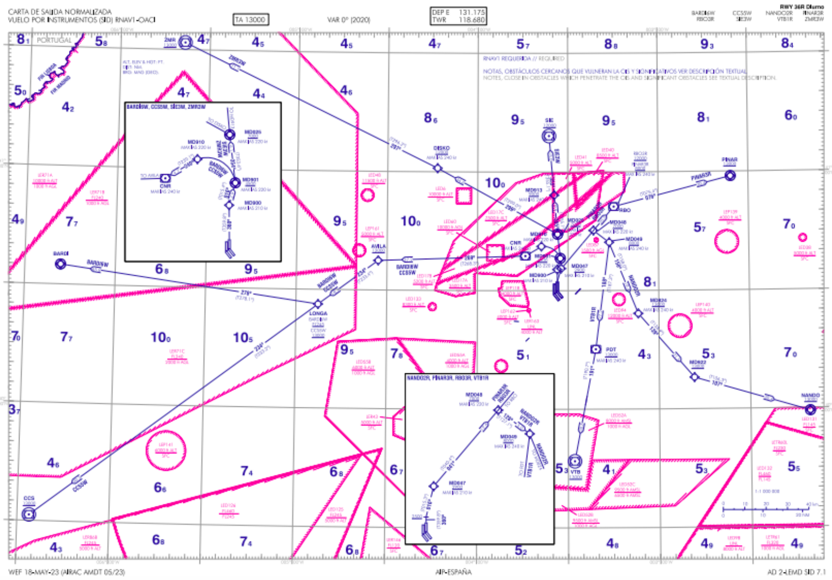

Figure 5:**SID7-RWY 36R Madrid**
(*ENAIRE, 2023*)

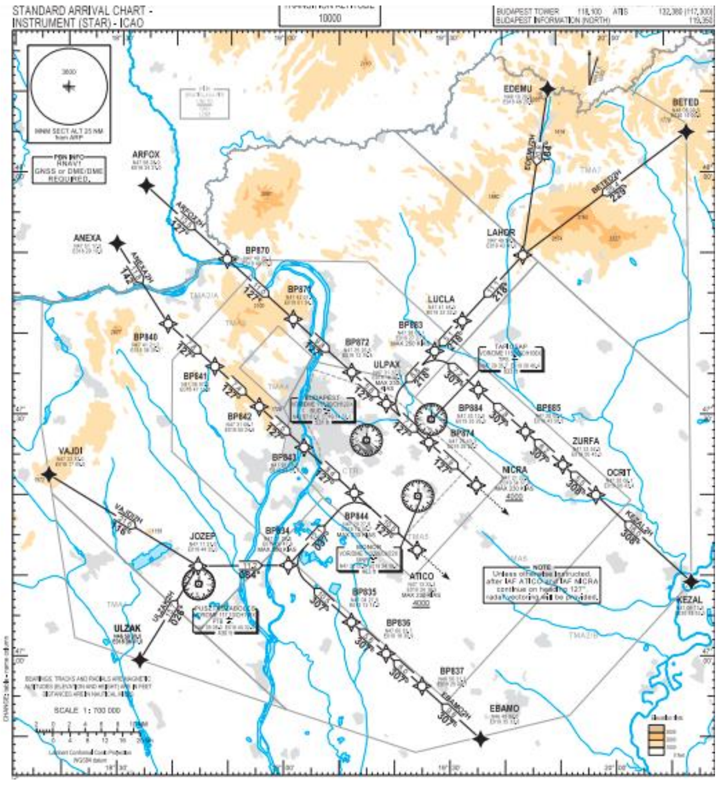

Figure 6: **STAR 31R/31L**
(*Eurocontrol, 2022*)

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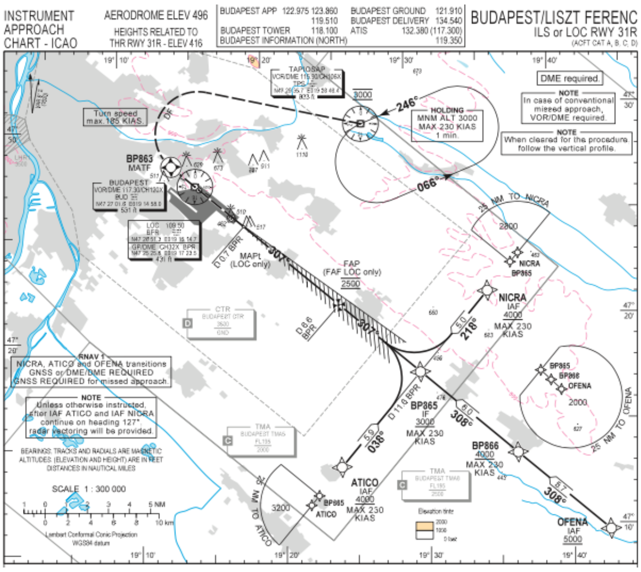

Figure 7: **Instrumental Approach chart-RWY31R**
(*Hungarocontrol, n.d.*)

On the one hand, the total distance in the orthodromic route would be 2026,87 km composed of the following distances between waypoints and the en-route distance:

Table 1: **Distance – Orthodromic route**

Waypoints	RWY 36R-PINAR	PINAR-ULZAK	ULZAK-ATICO	ATICO-RWY 31R
Distance	50.9 NM	978.52 NM	47.5 NM	17.5 NM

Own Compilation

On the other hand, the total distance in the loxodromic route would be 2031,98 km composed of the following distances between waypoints and the en-route distance:

Table 2: **Distance – Loxodromic route**

Waypoints	RWY 36R-PINAR	PINAR-ULZAK	ULZAK-ATICO	ATICO-RWY 31R
Distance	50.9 NM	981.27 NM	47.5 NM	17.5 NM

Own Compilation

A shorter flight distance implies less fuel consumption and reduced emissions. With the distances displayed above of the orthodromic and loxodromic routes, fuel consumption and the emissions of harmful gases such as CO_2 and NO_x will be reduced.

Using the fuel consumption data in litres per hour for each aircraft model of each airline that flies the route Madrid -Budapest, we reach the following fuel consumption using the orthodromic route.

Table 3: **Fuel consumption orthodromic route**

Airline	Aircraft model	Flight hours with the orthodromic route (h)	Total fuel with orthodromic route (l)
Iberia	A320	2.96	9247.9
Ryanair	B738	2.8	8664.3
Wizz Air	A321	3.1	9038.4

Own Compilation

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In the same way, using the loxodromic route:

Table 4: **Fuel consumption loxodromic route**

Airline	Aircraft model	Flight hours with the loxodromic route (h)	Total fuel with loxodromic route (l)
Iberia	A320	2.9667	9271.2
Ryanair	B738	2.90	8686.2
Wizz Air	A321	3.10	9062.2

Own Compilation

4. Analysis

To determine whether implementing the free route airspace is a successful way of improving the efficiency of the European airspace, we will compare our results of distances, fuel consumption, and emissions to the current airline data. Table 5 compares the main airlines that fly this route with each model of aeroplane they use:

Table 5: **Distances and fuel consumption of the current flight routes**

Airline	Aircraft model	km	Flight Hours (h)	Fuel Consumption (l/h)	Total fuel consumption (l)
Iberia	A320	2089	3.05	3125	9531.25
Ryanair	B738	2082	2.97	3000	8900
Wizz Air	A321	2093	3.2	2916.7	9331.2

Own Compilation

If we compare the data of Tables 4 and 5, we see how the distance and the fuel consumption are considerably lower following an orthodromic or loxodromic route. This is shown in Figures 8 and 9, depicting that the distance flown and the fuel consumption with the orthodromic route is the most advantageous.

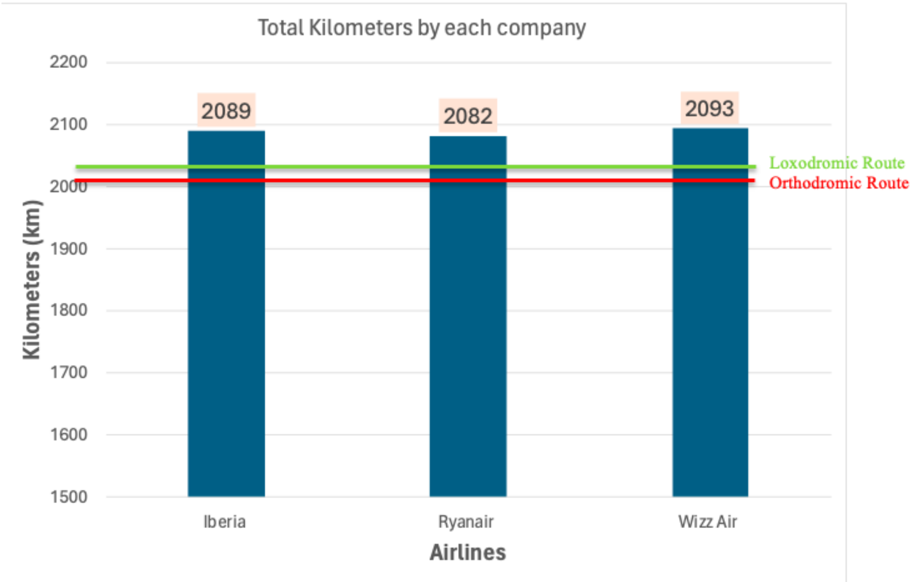

Figure 8: **Kilometers by each airline**
Own compilation

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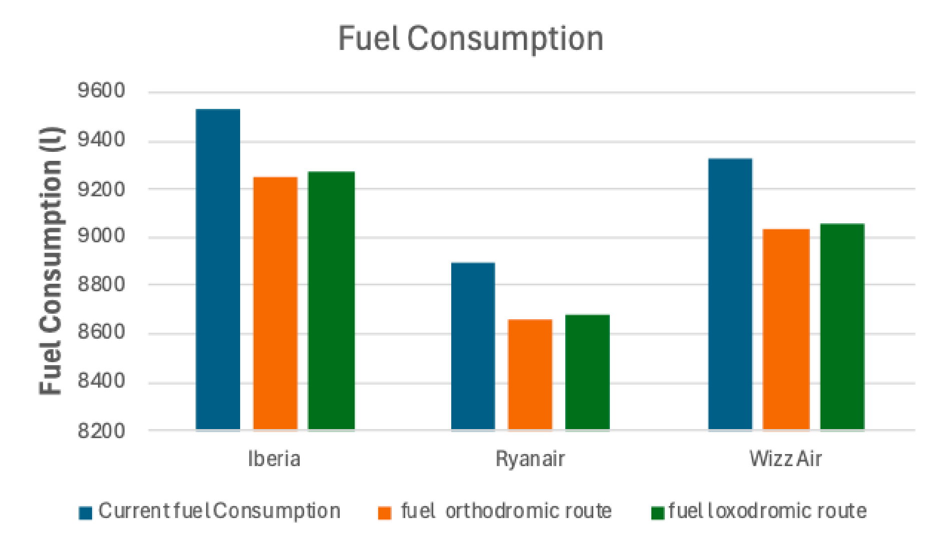

Figure 9: **Fuel consumption**
Own compilation

Consequently, a reduction in fuel consumption also implies a reduction in emissions. Therefore, it is important to examine each kilogram of fuel's impact on the environment. Out of all the emissions, the ones that most affect the atmosphere would be CO_2 and NO_X (*Benito, 2014*). CO_2 is the principal greenhouse gas due to kerosene combustion, and NO_X is responsible for creating ozone at high altitudes. The increasing presence of these gases in the atmosphere leads to global warming. Looking at Figure 10, we can study kilograms of each gas that would be put out in the atmosphere by one kilogram of fuel:

Table 5: **Emissions indices of climate change components**

Climate forcers at high altitude	EI from Ecoinvent database (kg/pkm)	EI from Emissions Indices at altitude database (kg/kg fuel)	EI from Emissions Indices at altitude database (kg/pkm)[a]
CO_2	8.10×10^{-2}	3.16	8.20×10^{-2}
H_2O	1.98×10^{-4}	1.23	3.20×10^{-2}
NMVOCs	3.27×10^{-6}	0.38×10^{-3}	9.85×10^{-6}
SO_4^{2-}	6.54×10^{-7}	1.20×10^{-3}	3.11×10^{-5}
CO	3.59×10^{-5}	3.00×10^{-3}	7.78×10^{-5}
NO_x	4.22×10^{-4}	15.14×10^{-3}	3.92×10^{-4}
Soot (BC)	/	0.03×10^{-3}	7.78×10^{-7}
Contrails-cirrus[b]	/	3.16	8.20×10^{-2}

Source: (*Watson et al., 2024*)

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Having the indices of each gas and the fuel consumption of each route and airline, the data presented in Figures 11, 12, and 13 can be calculated. These show the reduction of the amount of each gas if we used an efficient route.

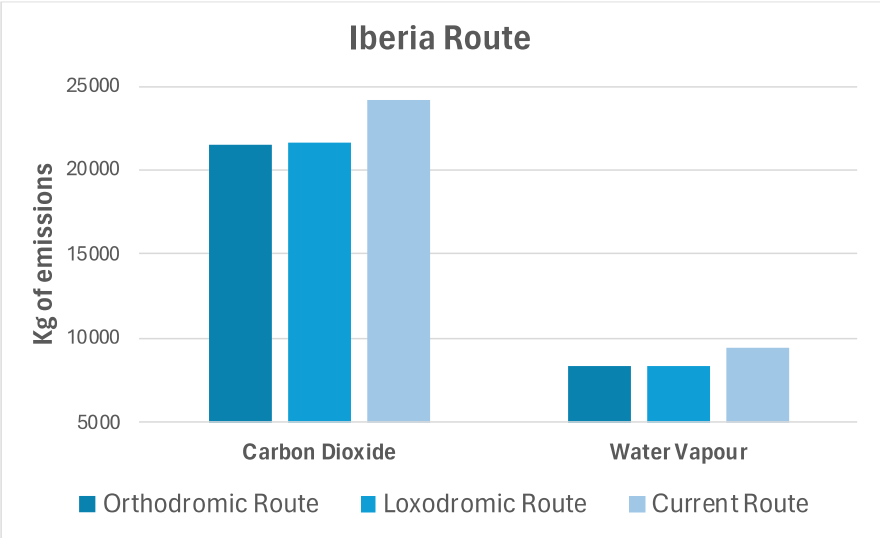

Figure 11: **Iberia´s gas emissions**
Own compilation

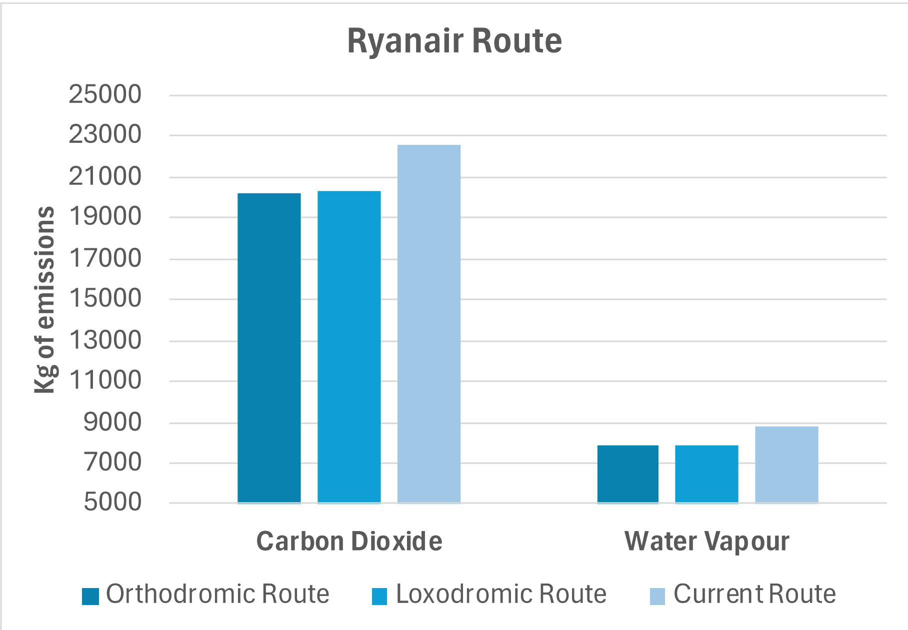

Figure 12: **Ryanair´s gas emissions**
Own Compilation

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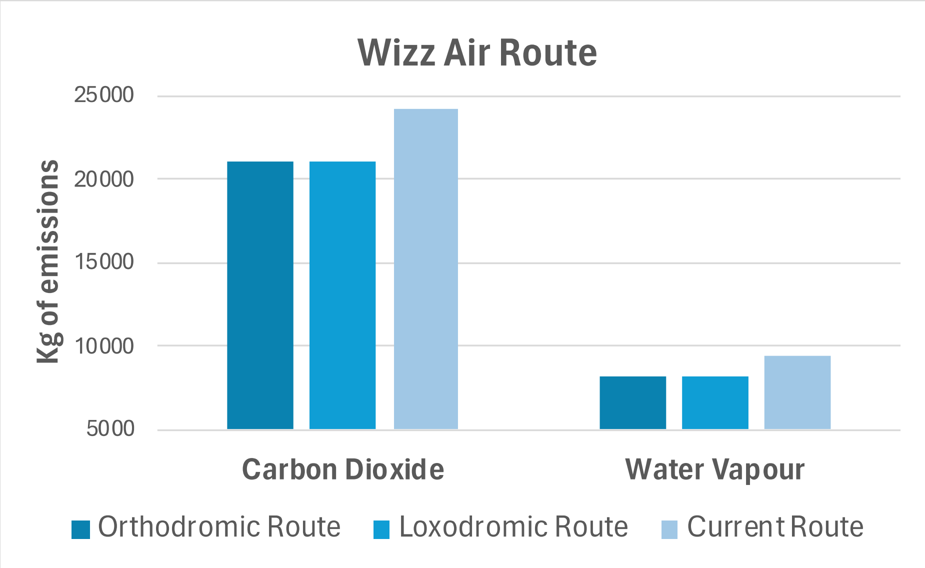

Figure 13: **Wizz Air´s gas emissions**
Own Compilation

5. Conclusion

It has been proven that the current state of European airspace is inefficient compared to other similar airspaces, such as the one in the USA. These inefficiencies include delays, suboptimal routing, and excessive fuel consumption, which contribute to increased operational costs and harm the environment. This study has demonstrated how the implementation of the SESAR initiative across Europe represents a pivotal advancement in revolutionising air traffic management and creating a more sustainable aviation ecosystem.

The case study of the Madrid–Budapest route demonstrates the advantages the SESAR initiative can accomplish. By adopting improved route planning techniques and switching from waypoint navigation to Free Route Airspace, we can reduce travelled distance; thus, the amount of fuel consumed can also be decreased. This implies cost savings for the companies and contributes to environmental preservation by minimising the carbon footprints associated with air travel. In addition, by maintaining the departure and arrival procedures on our route, commonly followed by the SID and the STAR, we approach the same goal and enhance the safety of our flights.

Furthermore, the successful implementation of the SESAR initiative may lead the European aviation industry towards sustainable growth, improved operational efficiency, and global competitiveness. As we navigate the complexities of the modern aviation landscape, the SESAR initiative stands out as a beacon of progress, pointing the way towards a time when air transport is economical, inventive, and dependable and ecologically conscious.

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Exploring strategies for streamlining security procedures without compromising safety: airport planning and logistical considerations

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Abstract
In the aviation industry, one principal aim is security and safety. On the one hand, governments are interested in globalising their countries and the security of their citizens and visitors while entering and leaving the country. On the other hand, for the aviation industry, it is imperative to guarantee the security of every process. Although aviation is known as the safest mode of transportation, it is the most criticised and scrutinised when an accident happens due to the potential passenger losses. Even if there were only one accident per year, the impact on the public eye would be fatal, and the aviation industry would not be the massive transportation system it is today. In this study, security processes will be analysed and studied through simulations. Apart from safety, another notable characteristic of aviation is the number of passengers who enter airports, take planes, travel, work, and use this system daily. This study focuses on optimising the processes without compromising safety levels. This paper presents various designs and optimisations for airport processing areas by studying parameters such as flight precedence, distribution over long journeys, human factors, and technology. Through this study, readers can better understand airport logistics and the significant influence of these parameters. Balancing all aviation elements is almost an art, requiring careful coordination and management.

Keywords
Airport, capacity, security

1. Introduction

This study optimises airport processing areas, such as security, passport control and customs (*Eurocontrol, 2024*). For that aim, it is important to be conscious that the types of flights determine the airport's infrastructure it will serve and the requirements for each kind of passenger. Higher levels of security are required at airports with international flights. This demand also determines the necessary space.

It is possible to calculate the best space utilisation for each process listed above and introduce new technologies to help use those spaces better. It must not be forgotten that capacity in the aviation industry is limited. With the growing demand for flights, adapting these spaces for maximum efficiency is crucial.

1.1. Literature review

The first step in focusing on this project was to study the field and the correlation between its components. A map based on 1000 articles by ScienceDirect related to airport and aviation security has been elaborated. From this data, we created a conceptual map (*Figure 1*), which helps us understand the importance of and the connections between the elements of the system. The most important focal points are the following concepts: airport and airports, airport terminal, airport security and security, airport quality, airport management and aviation.

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Airports and airports are the centres of this research. At airports, thousands of passengers must deal with obstacles in a sometimes new environment. Airport management and quality are strongly connected to studying common concerns such as infrastructure, passenger satisfaction, privatisation, or airport regulation (*Bolić, Ravenhill, 2020*).

On the other hand, there is no strong relationship between airport management and airport security, which is the main problem this paper aims to study. The concept of an airport terminal is not strongly related either. These two fields are interesting ones that are related to developing a better airport security process (*Calzada, Fageda, 2023*). Furthermore, airport security research dates back to 2015, while the remaining elements are more recent. This is another reason why this field must be investigated.

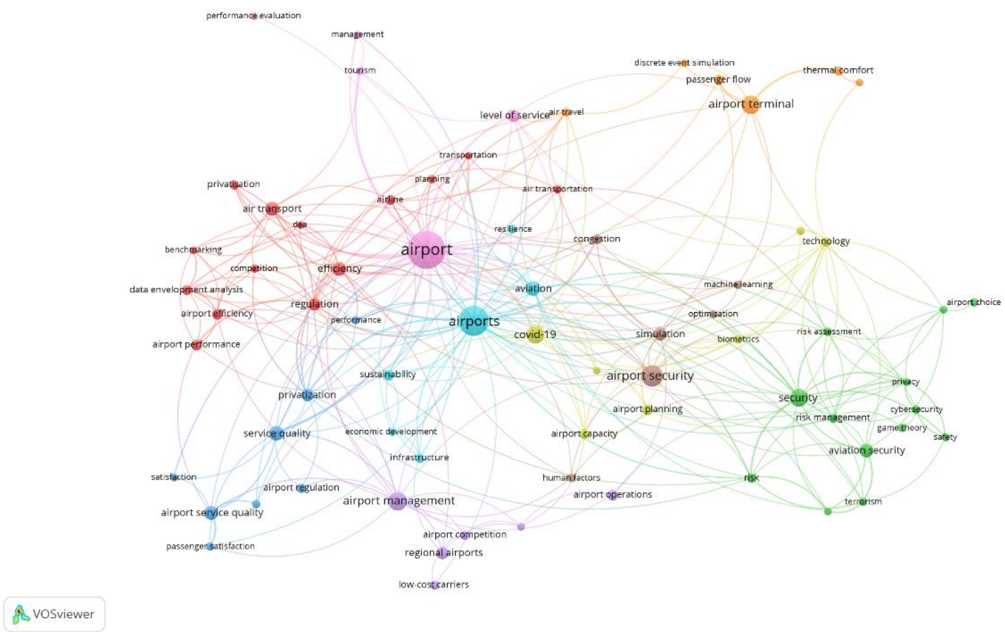

Figure 1. **Conceptual map of the investigated articles**
Source: VOSviewer made by the author

Airport security is an important, up-to-date topic. In this article, the security counters are investigated. The elaborated model also reflects the cognitive attributes of passengers.

2. Data and methods

In this article, the author shows the development of the security counters process. The key indicator is the maximum waiting time for the security process (*Rosenow et al., 2020*). Therefore, the following data had to be gathered about the passengers:

1. Maximum waiting time at security counters: t_{max}
2. Time to process of security check: t_p
3. Number of passengers: PAX
4. Real distribution of passenger's arrivals

From this data, the number of necessary security counters can be obtained. The first step is to compare an ideal distribution of arrivals and the real one over a while.

Table 2. **Comparison between an ideal distribution of arrivals and the real one**

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TIME (min)	0	6	12	18	24	30	36	42	48	54	60
% REAL arrivals	0%	10%	25%	40%	80%	90%	95%	97%	98%	99%	100%
% IDEAL arrivals	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

Source: own compilation based on Heathrow. (2024)

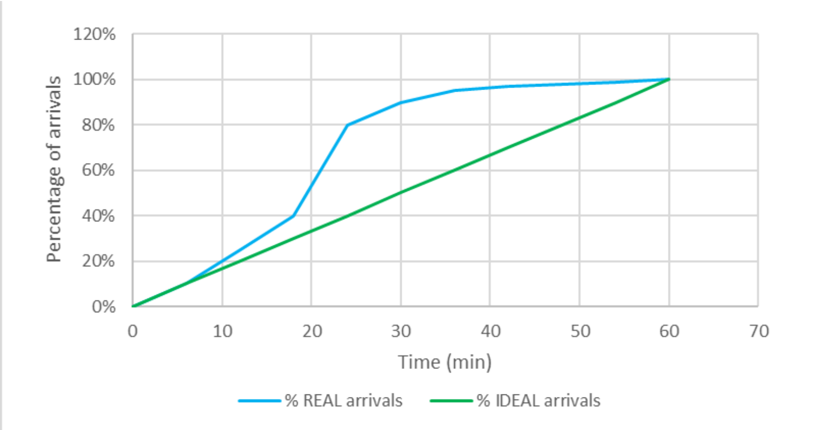

Figure 2. **Graphic comparison between an ideal distribution of arrivals and the real one**
Source: own compilation based on Heathrow. (2024)

There is a capacity problem when the slope of the real arrivals is higher than the slope of the ideal arrivals. This implies that an accumulation of passengers is occurring, and they will have to wait. For example, Figure 2 shows that between minutes 12 and 24, 65% of the total passengers arrive. While between minutes 48 and 60, just 2% of them.

The formulas used for the calculations are:

$$IS = \frac{PAX*tp}{60} \qquad (1)$$

where,

IS is the Initial Score, an initial approximation of the number of counters if the passenger's arrival was ideal,

PAX is the number of passengers,

tp is the time to process.

$$NC = \frac{(\boldsymbol{PAXf - PAXi})*\boldsymbol{PAX * tp}}{\boldsymbol{tf + ti - tmax}} \qquad (2)$$

where,

PAX_f is the final number of passengers of a certain period where the accumulation happens,

PAX_i is the initial number of passengers of a certain period where the accumulation happens,

PAX is the number of passengers,

t_p is the time to process,

t_f is the final moment where the accumulation ends,

t_i is the initial moment where the accumulation starts,

t_{max} is the maximum waiting time.

The final step will be to calculate the number of counters for each period (*Table 2*):

Table 2. **Counters for each period**

Period (min)	Counters
0–12	14
12–24	30
24–60	6

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** Please note that the dínamics of demand are different; therefore, a flexible number of security counters are open. That is the reason why the dynamics of opening are not equidistant.*

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3. Results and discussion

3.1 Arrivals study

The results for the basic scenario (ideal arrival) and realistic scenario (real arrival) are represented in (Table 1). The average number of counters for this example was 23 counters. However, let us analyse the real arrival distribution: Each period has a t_{max} of 13 min. These 30 counters of the (12–24) period cannot be closed on minute 24 because there are 13 extra minutes of queue and accumulated people.

So, this process concludes that starting with 14 counters will be enough. However, by minute 12, 30 counters should be opened to avoid the formation of an excessive queue. From minute 37, counters can progressively close until six remain open because the accumulation is decreasing.

3.1.1 Arrivals study: Waiting time depending on the type of flight

For this case, three different types of flights were taken into account: European Union and Schengen Area (UE SCH), International Short Range (INT SHRT), and International Long Range (INT LNG). At the same hour, the passengers of these three destinations will arrive with different waiting times.

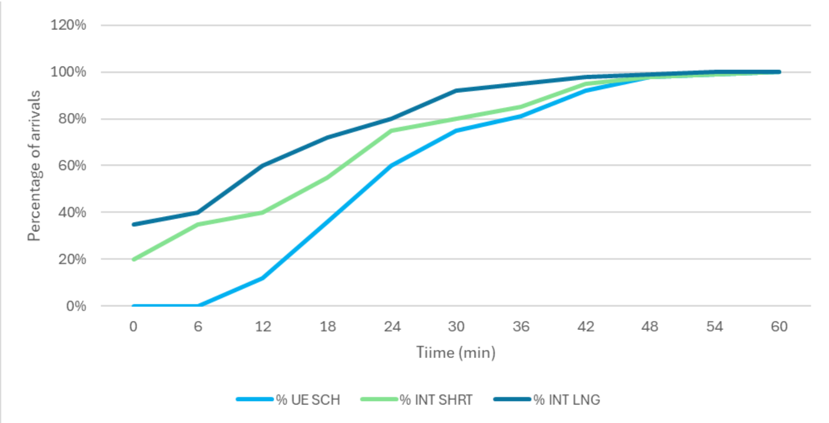

Figure 3. **Comparison of arrivals depending on the type of flight**
Source: own compilation based on NZ Pocket Guide (2024)

As shown in *Figure 3*, there is more waiting time for processing times in the case of International Short Range arrivals compared to the European Union Schengen flights, but the processing time for International Long Range arrivals is significantly higher than for the other categories. This data is representative and will differ depending on the circumstances in every airport.

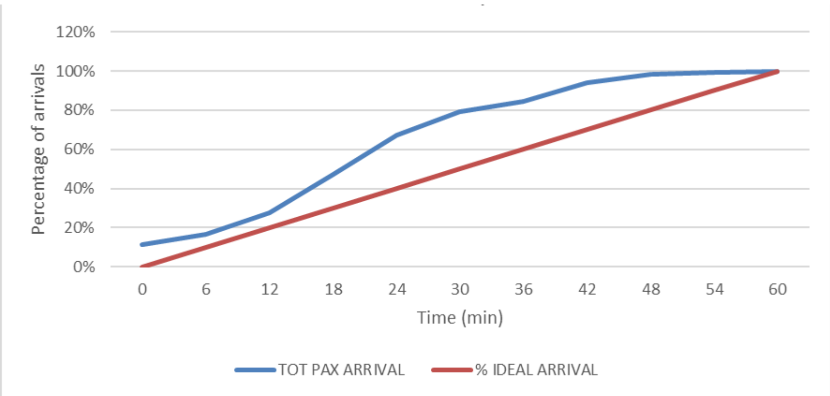

Figure 4. **Graphic comparison between an ideal distribution of arrivals and the real one**

The results were obtained using the following parameters.

- $t_{\max}$: 13 minutes
- t_{p}: 40 seconds per passenger
- PAX (UE SCH): 2000 passengers
- PAX (INT Short Range): 1000 passengers

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- PAX (INT Long Range): 600 passengers

And the results:

Table 3. **Counters for each period**

Period (min)	Counters
0–6	20
6–30	41
30–60	17

** Please note that the dínamics of demand are different; therefore, a flexible number of security counters are open. That is the reason why the dynamics of opening are not equidistant.*

Due to the necessity of maximising capacity and the following necessity of more counters from minute six, the periods of (0–6) and (30–60) have been calculated for a maximum waiting time of zero ($t_{max} = 0$). That means initially, 20 counters must be opened to avoid a queue. Then, at minutes 6 and 21, more counters must be opened, and the maximum waiting time will be 13 minutes. Again, this number will be reduced to 17 counters for the last half an hour without waiting times. With this $t_{max} = 0$ decision, initial accumulation will be reduced to zero, concentrating the work on the following 24 minutes. Also, the passengers who are more impatient or hurried for the last 30 minutes will pass instantly. The decision to have the maximum number of counters from the beginning (41) is not feasible because most will be unexploited. This is a scenario where there is just one operation hour. In a real airport with a normal distribution of passengers, it will come and go, so these drastic opening and closing decisions should not be made. Now, we will study the case of a complete journey.

3.1.2 Arrivals study: Study of the arrival distribution in peak morning period

Airports are infrastructures that work most of the day, if not 24 hours. Thus, even if correct, the study of only one hour of operation is unrealistic. Figure 5 shows the different arrival distributions from 8 AM to 12 AM every hour. Also, as we have seen in previous examples, the real distribution of the total passengers will be compared to their ideal distribution.

Table 4. **Distribution of arrivals along a day and comparison of real and ideal distribution of arrivals**

TIME (min)	240	225	210	195	180	165	150	135	120	105	90	75	60	45	30	15	0
8 h - 9 h	5%	20%	65%	80%	100%												
9 h - 10 h					0%	35%	70%	85%	100%								
10 h - 11 h									0%	10%	45%	75%	100%				
11 h - 12 h													0%	40%	80%	100%	100%
IDEAL %	0%	6%	13%	19%	25%	31%	38%	44%	50%	56%	63%	69%	75%	81%	88%	94%	100%
REAL %	0,8%	3%	11%	13%	17%	32%	47%	53%	59%	62%	72%	80%	87%	92%	97%	100%	100%

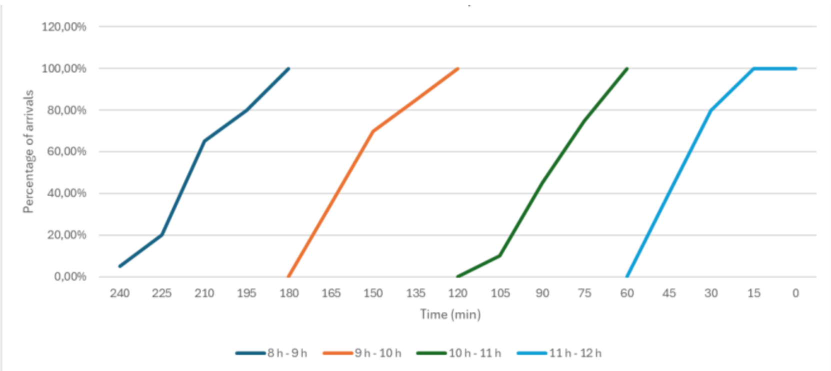

Figure 5. **Distribution of arrivals for each hour of operation**

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Following the previously explained procedure, and with these data:

- t_{max}: 5 minutes
- t_p: 40 seconds per passenger
- PAX (8 AM – 9 AM): 789 passengers
- PAX (9 AM – 10 AM): 2000 passengers
- PAX (10 AM – 11 AM): 1300 passengers
- PAX (11 AM – 12 AM): 600 passengers

The results obtained are:

Table 5. **Counters for each period**

Period (min)	Counters
240–210	2
210–135	10
135–0	5

3.1.3 Arrivals study: Study of the human factor and its consequences on processing times

For this part of the study, I assumed that passengers could have different cognitive attitudes and profiles that we could incorporate into the processing time (*Knol, Sharpanskykh, Janssen, 2019*), following *Table 6*. I focused on factors that influence the capacity of the security process, specifically human factors. Firstly, I divided each passenger profile according to the processing times. With a standard processing time of t_p = 30 s/pax, we will find:

Table 6. **Different processing times depend on the human factor**

Profile of the passenger	Processing time (s/pax)
Standard passenger	30
Passengers that increase the t_p	
First flight	75
Older than 60 years	60
Disabled	120
Passengers that decrease the t_p	
Business passenger	20

Now that every t_p is established, it is necessary to know which percentage of the total each profile of passenger supposes:

Table 7. **Proportion of each kind of passenger**

Human factors	% of the total PAX	Number of PAX
% Standard	48%	1440
% First flight	20%	500
% Older than 60	35%	875
% Disabled	0,4%	10
% Business	7%	175

To continue, it is important to know the distribution of the passengers by cognitive attitude. It is visible how the profile affects the processing times, the waiting time, and the distribution of arrivals.

Table 7. **Distribution of arrivals of every profile of passenger**

TIME (min)	0	6	12	18	24	30	36	42	48	54	60
% Disabled	0%	0%	50%	50%	50%	50%	50%	100%	100%	100%	100%
% First flight	0%	7%	25%	38%	60%	79%	95%	100%	100%	100%	100%
% Older than 60	1%	10%	22%	45%	53%	70%	89%	98%	100%	100%	100%
% Bussiness	0%	0%	4%	9%	16%	20%	37%	67%	85%	99%	100%
% Standard	1%	3%	15%	34%	48%	60%	67%	79%	88%	95%	100%

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In the next figure (Figure 6), Table 7 will be represented graphically. We can appreciate that, while first flight or older passengers seem to act with the same waiting time, business passengers, who are more experienced and usually carry less baggage, come with less waiting time.

This data is representative of creating a functional model. Every distribution of arrivals will depend on many factors and will be different for each airport.

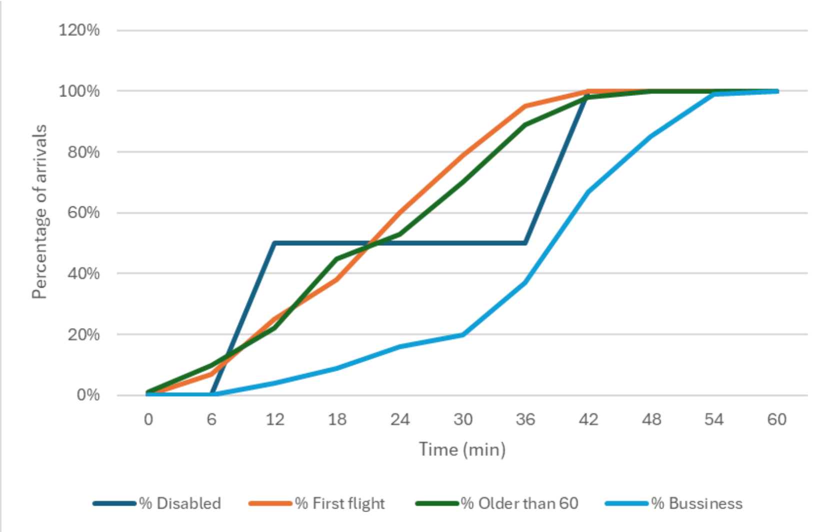

Figure 6. **Different waiting times depending on the cognitive attitude**

The following data was employed for this scenario:

- t_{max}: 10 minutes
- t_p: Table 14. Different processing times depend on the human factor
- PAX (total): 2500 passengers

The number of counters was calculated specifically for each passenger profile:

Table 8. **Number of counters on the period of 6–42 min for every type of passenger**

Human factors	**NC (6, 42)**
Standard	12
First flight	13
Older than 60	17
Disabled	1
Business	1

The number of counters is 43 if the above parameters are used.

This process was repeated for the last period, from minute 42 to 60:

Table 9. **Number of counters for 42–60 min for every type of passenger**

Human factors	**NC (42, 60)**
Standard	6
First flight	0
Older than 60	1
Disabled	0
Business	1

This gives us a total of 7 counters rather than eight because these values are approximations of the real ones, resulting in a final approximation of 7.

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3.2 Study of the new technologies applied in airports

In the following example, the size of the area is studied. The total space dedicated to the counters is taken to be 200 m^2. The area occupied by biometric counters is 3 m^2, and for standard counters: it is 6 m^2.

Table 9 compares the following values:

A) Maximum capacity of the process: where 100% of the counters are biometric, with space for 67 counters, and with the processing time of 30 seconds per passenger, the 8000 passengers processed in an hour.

B) Minimum capacity of the process: where 100 % of the counters are standard, with space for 33 counters, and with a processing time of 60 seconds per passenger, just 2000 passengers can be processed in an hour.

Table 10. **Capacity of the process**

	Number of counters	**t_p (min/pax)**	**Capacity of the process (pax)**
Max (all biometric)	67	0.5	8000
Min (all standard)	33	1	2000

In this example, we have 200 m^2 available for the counters. However, putting just biometric or standard counters is unrealistic; some passengers will not be compatible with technology, and the airport may not allow a complete reconstruction of the installations (*Hättenschwiler et al., 2018*). So, *Figure 7* shows the maximum coexistence that can exist in every case and the combination of standard and biometric counters (*Sánchez del Río et al., 2016*). The space relation is simple in this case: two biometric counters for every standard one.

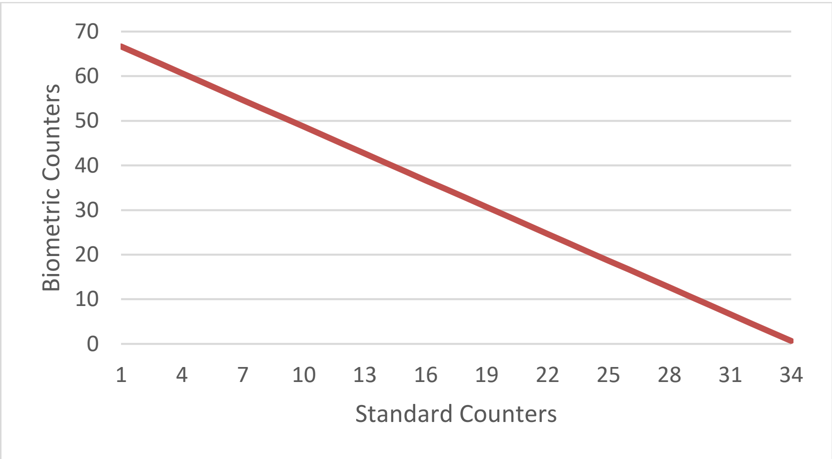

Figure 7. **Counters coexistence relation**

The next step for every combination of counters is calculating the number of passengers that can be processed. Every combination will have a specific number of passengers for biometric and standard counters to ensure maximum economic effectivity (*Kirschenbaum, 2013*).

In a specific case studied, 1800 passengers are compatible with biometric counters and 700 with the standard one:

Table 11. **Counters and areas occupied for the specific case**

	Number of pax	**Number of counters**	**t_p**	**Area**	
Biometric	1800	**15**	0,5	45 m^2	
Standard	700	**12**	1	72 m^2	
	TOT =	**27**		**117 m^2**	**< 200 m^2**

As a result, the optimal numbers of counters were considered a dynamic of arrival, the modification factor of the cognitive attitude, and the existing technologies.

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4. Conclusion

In this article, the aviation industry's security, especially the security counters, was investigated. On the one hand, governments are interested in globalising countries and protecting citizens and visitors when they enter and leave countries. In the aviation industry, however, the security of each process is vital. Aviation is known to be the safest mode of transportation, but accidents due to the possibility of passenger losses are the most criticised and scrutinised. Even if only one accident happens yearly, the impact on the public's eye will be fatal, and the aviation industry will not be the enormous transportation system it is today. In this study, security processes are analysed and studied by simulation. In addition to safety, there are also notable features of air transport, such as the number of passengers entering airports, using aircraft, travelling, working, and using the system daily. The study focuses on optimising processes without compromising safety standards. The main objective was to build a solid framework to optimise the number of security encounters focusing on the dynamic of arrival, the modification factor of the cognitive attitude, and the existing technologies. This paper examined factors such as flight priority, long-haul distribution, human factors, and technology and presented various design and optimisation issues for airport security processing. The study enables readers better to understand the importance of airport logistics and these parameters.

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What is the difference between climate resilience and climate resistance in transport infrastructure?

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Abstract

In this paper, the author is willing to define resilience. Then, the paper will focus on developing transport resilience, adaptability, absorption, human factors, and recovery. Also, the author defines the resistance and its connection to transport. Finally, the author tries to build up the difference between resilience and resistance and help reveal the cognitive dissonance between resilience and resistance.

Keywords
transport resistance, cognitive dissonance, transport resilience

1. How does climate resilience in transport infrastructure differ from climate resistance?

The impact of climate resilience and climate resistance on the design and maintenance of transport infrastructure involves understanding the challenges and opportunities associated with integrating these concepts into transport infrastructure planning and development (*Maternová, Materna, Dávid, 2022*). Considering the environmental and economic implications of prioritising climate resilience over climate resistance in this context is essential.

– *Climate Resilience* refers to the ability of transport infrastructure to absorb and recover from climate-related disruptions, emphasising adaptability and flexibility (*Chirisa et al., 2023; Hayes et al., 2019*)

– *Climate Resistance* focuses on the ability of infrastructure to withstand and resist climate-related impacts, often through traditional engineering approaches (*Hayes et al., 2019*)

Climate resilience in transport infrastructure emphasises the need for paradigm shifts in engineering, planning, and design, requiring a framework for evaluating benefits in financing adaptation projects to improve resilience (*Martello and Whittle, 2023; Armstrong et al., 2014*). Meanwhile, climate resistance often aligns with a traditional "engineering resilience" approach, which involves increasing the strength and rigidity of assets to withstand the impacts of climate change (*Hayes et al., 2019*).

Challenges include a lack of data and knowledge on climate change impacts, difficulties in designing and prioritising remedial actions, issues with budgeting and planning for climate change, and the need to identify and engage with stakeholders (*Greenham et al., 2023*). Opportunities lie in developing practical, relevant, and usable data, tools, advice, and support for at-risk transport networks to climate change, as well as leveraging socio-ecological resilience theory and biomimicry for resilient and regenerative infrastructure (*Hayes et al., 2019; Greenham et al., 2023*).

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Figure 1. **Conceptual figure: difference between resilience and resistance**

Source: Copilot AI drawing based on the article

Prioritising climate resilience over climate resistance can lead to improved road infrastructure design, proactive maintenance, and reduced vulnerability to hazards, ultimately minimising the impact of climate change (*Biosca Amat et al., 2022*). Furthermore, the ongoing climate change is expected to increase its impact on transport infrastructures, exposing people to unacceptable risks, thus necessitating more frequent adoption of prevention and protection measures for collective safety (*Moretti and Loprencipe, 2018*), (*Galieriková, et al., 2021*).

Integrating climate resilience and resistance in transport infrastructure planning and development presents challenges and opportunities with implications for transport networks' environmental and economic sustainability. While climate resilience emphasises adaptability and flexibility, climate resistance focuses on withstanding and resisting climate-related impacts, both of which are crucial for the long-term sustainability of transport infrastructure. In this paper, the author explores and compares these two topics.

2. What key factors contribute to climate resilience in transport infrastructure?

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The key factors contributing to climate resilience in transport infrastructure include environmental factors, technological advancements, economic considerations, and policy and governance factors.

Climate change poses significant threats to transportation infrastructure, including rising temperatures, increased flood risk, and other potential hazards (*Chirisa et al., 2023*). Extreme weather events such as heat waves, wildfires, drought, flooding, tropical storms, and heavy downpours have the potential to become more frequent and severe. These may damage transportation infrastructure and result in expensive repairs (*Holsinger, 2017*). Climate change and sea-level rise pose significant threats to transportation infrastructure in coastal cities, necessitating an understanding of projected future climate extremes and their impacts on the transportation system (*Martello and Whittle, 2023*).

Technological advancements that contribute to climate resilience in transport Infrastructure need to be investigated. Firstly, paradigm shifts in infrastructure engineering, planning, and design are required to improve the resilience of transportation infrastructure systems, necessitating new frameworks for evaluating benefits in financing adaptation projects to improve resilience (*Martello and Whittle, 2023*). Leveraging socio-ecological resilience theory and innovation inspired by nature (biomimicry) can support resilient and regenerative infrastructure, introducing potential tools and frameworks for enhancing climate resilience in transport infrastructure (*Hayes, 2019*).

Also, economic considerations must be formulated to enhance climate resilience in transport infrastructure. Efforts to decrease the vulnerability of transport networks have been largely limited to understanding projected risks through governance and administrative efforts, with physical adaptation measures typically aligned with a traditional “engineering resilience” approach (*Markolf et al., 2019*). A life-cycle resilient performance measurement framework can comprehensively capture the significant underlying perspectives for understanding the current resilience level of transport assets. Such measurement results and measures taken based on them may lead to a higher ability of the assets to adapt to environmental changes in the future (*Liu et al., 2019*).

Finally, the third key factor is policy and governance, which influence climate resilience in transport infrastructure. A prioritisation framework and case study have been presented addressing climate change adaptation for transportation infrastructure, based on the outcomes of engineering assessments, development of policies for including risk as part of decision making, and methods for prioritising improvements to reduce/eliminate risks to the existing network (*Armstrong et al., 2014*). The responsibilities of EU Member States and critical entities in increasing their resilience to current and supposed future risks have been addressed. Additionally, a framework for assessing the resilience of critical entities in the transport sector has been proposed, along with possible adaptive measures to increase resilience to the adverse effects of climate change (*Luskova and Leitner, 2021*).

The key factors contributing to climate resilience in transport infrastructure encompass environmental factors, technological advancements, economic considerations, and policy and governance factors. These factors are crucial for understanding and addressing the challenges climate change poses to transportation infrastructure.

3. How can climate resistance be integrated into the transport infrastructure design?

The following insights can be derived from the literature on integrating climate resistance into transport infrastructure design. Climate change and extreme weather events pose significant risks to transportation infrastructure, including damage and loss of service (*Holsinger, 2017; Martello and Whittle, 2023; Liu et al., 2023*). Transport infrastructure is vulnerable to climate impacts due to its long operational life and susceptibility to deterioration and disruption (*Picketts et al., 2016*). There is a growing concern for the resilience of transportation infrastructure in the face of climate change and extreme weather events (*Martello and Whittle, 2023; Armstrong et al., 2014*).

There are existing strategies for policy integration. *Adaptation Planning*: Integrating climate resistance involves incorporating climate change considerations into infrastructure planning, design, and maintenance (*Liu et al., 2023; Picketts et al., 2016; Armstrong et al., 2014*). *Multi-Dimensional Approach*: Climate-resilient transportation infrastructure requires paradigm shifts in engineering, planning, and design, as well as the development of new frameworks for evaluating benefits in financing adaptation projects even at the social level (*Martello and Whittle, 2023*). *Risk Assessment and Prioritisation*: A framework based on engineering assessments and developing policies for including risk in decision-making can help identify at-risk facilities and prioritise improvements (*Armstrong et al., 2014*).

4. What cognitive techniques differentiate transport resistance and transport resilience?

The author faced the fact that, in some cases, experts even used resilience and resistance as synonyms. This last section of the paper thus focuses on defining and enlarging the cognitive gap. Transport resistance refers to a system's ability to withstand external shocks or disturbances without significantly disrupting its functioning. It encompasses several key aspects, such as robustness, which relates to how well the system can function according to its design specifications for integrated modes and routes before any perturbations occur. Also, redundancy is very important, as it measures the degree of duplication of traffic routes and alternative modes. It helps maintain service persistence during disruptions.

Meanwhile, transport resilience describes how fast the system can be restored after perturbations. This could include resourcefulness the capacity to identify operational problems, prioritise interventions, and mobilise necessary resources for recovery. Additionally, rapidity is crucial; it describes the speed at which the system fully recovers all modes and traffic routes in the urban area.

Moreover, transport resilience refers to a system's ability to absorb disturbances, maintain its basic structure and function, and recover to a required level of service within an acceptable time and cost after disruptions. Key characteristics of transport resilience include adjustment, which means how a resilient system can adapt its functioning before, during, and after changes or disturbances. Continued performance is also important: the system performs as required, even after a disruption or major mishap. However, stress tolerance is also considered here: the system operates effectively under continuous stress.

As for a small amount of theoretical criticism of cognitive science in terms of discovering the differences and similarities, the author defines cognition as a concept encompassing various mental processes involved in acquiring knowledge, manipulating information, and reasoning. It includes understanding and distinguishing between similar words or concepts. From this, one could easily derive cognitive abilities, which describe a person's capacity to process information, solve problems, and adapt to new situations. Cognitive abilities help us discern subtle nuances and context-specific meanings when comparing synonyms. Intelligence involves overall cognitive functioning, describing the adaption capability of a person. It enables us to recognise synonym distinctions based on context, connotations, and usage. Being aware of language nuances and semantic variations aids in understanding synonyms. It involves recognising when to use one term over another. Insightful individuals can grasp deeper meanings and subtle differences between synonyms. They consider context, tone, and cultural implications. The ability to comprehend complex ideas and nuances helps us appreciate distinctions between synonyms. It involves grasping both denotative and connotative meanings.

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