ARTIFICIAL INTELLIGENCE AND TOURISM IN THE EU: A DATA-DRIVEN ANALYSIS OF ADOPTION AND ECONOMIC CONTRIBUTION

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Abstract
Tourism is continually shaped by emerging technological innovations. Artificial intelligence (AI) is also rapidly transforming the travel industry by enhancing operational efficiency, optimizing cost management and improving the customer experience. With the help of AI, experience is personalized, accommodation services are automated, and consumer decision-making is assisted. This paper deals with the role of AI in the tourism of EU countries, its benefits and future expectations of the global market. The data base consisted of the global AI index, its dimensions, the share of GDP for tourism in the total GDP for 2019. We rely on the analysis of the main components as the basis of our chosen methodology. This method is recognized for data visualization, helping to reveal correlations between quantitative variables. We also applied cluster analysis and biplot visualization to identify interrelationships and patterns in the data set. The main goal of the paper is to provide a more comprehensive overview of the latest AI solutions and their application in tourism. In our analysis, we evaluate important AI innovations that will continue to shape the future of tourism, such as virtual assistants, chatbots, predictive assessments or biometric technologies. We also analyze the uniformity in the use of AI in a set of EU countries in the context of the share of tourism in GDP creation. The presented paper highlights potential future trends that are likely to play a significant role in sustainable and intelligent travel. The role of AI in tourism is substantial and is expected to expand as countries want to use customer experiences and optimize their business strategies and operations based on them. Our results demonstrate the uneven distribution of AI development in tourism across EU countries. We identified differences depending on infrastructure, talent, commercial integration and applied public policy. Based on the previous review of AI applications in tourism, we suggest specific AI steps that similar countries in each cluster should take to increase the importance of tourism in their economies through the effective use of AI technologies.

Key words
Tourism, artificial intelligence, business, customer, sustainability.

INTRODUCTION

Tourism sector is influenced and shaped by new technologies like never before. Easy and comfortable access to new tools such as chatbots, virtual assistants, online reservations, virtual tours, personalized recommendations or digitization are reshaping customer behavior. Today, tourism is no longer only about physical travel, but thanks to rapidly advancing technologies, it is also about data-driven experiences. They primarily bring significant flexibility to customers, access to the entire spectrum of information and also comfort. These transformational changes give rise to new business models and services that reflect the dynamics of the current era and the rapidly changing expectations of travellers. Artificial intelligence (AI) has become a significant driving force in this context, driving innovation and transformation. AI tools help not only to process and evaluate a large set of data quickly, but also effectively, which allows tourism actors to predict possible trends in further development, and also predict customer behavior. There is also an increase in the level of personalization, which is a key aspect to maintain and increase traveler satisfaction. AI can be an important help for travel agencies, accommodation facilities, transport companies in the light of adapting the offer to the individual needs and preferences of customers. These are then reflected in visiting and formulating recommendations for specific destinations, improving communication in real time or customizing the itinerary. AI as a technological breakthrough, helps automate many processes, ranging from chatbots to predictive equipment maintenance or capacity management. The increased demand needs to be effectively managed, which is again a space for AI. This increases transparency and sustainability by optimizing the use of resources and eliminating the carbon footprint of travellers. In this paper, we focus on the role of AI in tourism and its benefits to the industry itself. Tourism is a highly innovative industry and must respond to the changing expectations and needs of the global market. We also dedicate space to possible future development directions related to the implementation of AI. These include cyber security, privacy or ethical issues related to automation.

As the consumer behavior models and consumer expectation are changing, the demand for innovative solutions is increasing. These can shape the way travellers have interacted with destinations so far. Technological solutions offer a more convenient choice, planning and experience of trips. Digitization in tourism brings such revolutionary tools as online reservations, virtual tours, personalized recommendations. Thanks to them, travellers have an opportunity to obtain a large amount of information that helps them in their decisions about the choice of services in the tourism industry. The position and role of artificial intelligence

tools in business and on a global scale is undeniable. Bughin et al. (2018) on behalf of the McKinsey Global Institute conducted research focused on the simulated impact of AI on the world economy. Special attention was paid in the research to the adoption of AI technologies. The results of their findings suggest that artificial intelligence tools have great potential to contribute to global economic activity.

However, they also reveal the risk of deepening disparities between individual regions and countries. Chui, M. et al. (2018) also, representing the McKinsey Global Institute, claim in their report that modern AI tools can be 128% more efficient in the tourism industry compared to conventional analytical methods. The research also focused on the evaluation of 18 other industries, but in the case of tourism it is the highest rate.

THEORETICAL FRAMEWORK

In addition to the fact that artificial intelligence transforms and innovates processes across the entire provision of services in the tourism industry, it has the ability to change or transform the potential and productivity of GDP at the level of the global economy. A prerequisite for meeting these goals of macroeconomic indicators are numerous investments in various types of artificial intelligence (PwC, 2017). Chi Software Company (2024) described the application of artificial intelligence in tourism as a revolution and explored the transformation of tourism by digital artificial intelligence through artificial intelligence applications. The findings are reported in their study and shown in Figure 1.

Figure 1 illustrates the potential added value of artificial intelligence compared to other analytical techniques. Axis X represents the percentage share of the impact of artificial intelligence on the total impact based on the analysis conducted. According to a McKinsey Company report, modern artificial intelligence analytical solutions are up to 128% more effective in the case of tourism compared to conventional analytical methods. This value is the highest among the other eighteen examined branches of the national economy. We note that the average value was found at the level of 62%. At the same time, the same research quantified the largest value generated by the application of artificial intelligence for tourism at the level of approximately 400 billion USD. It means a significantly higher contribution value compared to other areas. The quantified point for tourism is indicated by a pink dot directly in the graph. For entrepreneurs in the field of hospitality and tourism, artificial intelligence has a very inspiring effect and encourages the development and implementation of software solutions for the development of tourism, even for its significant decline in the previous pandemic period.

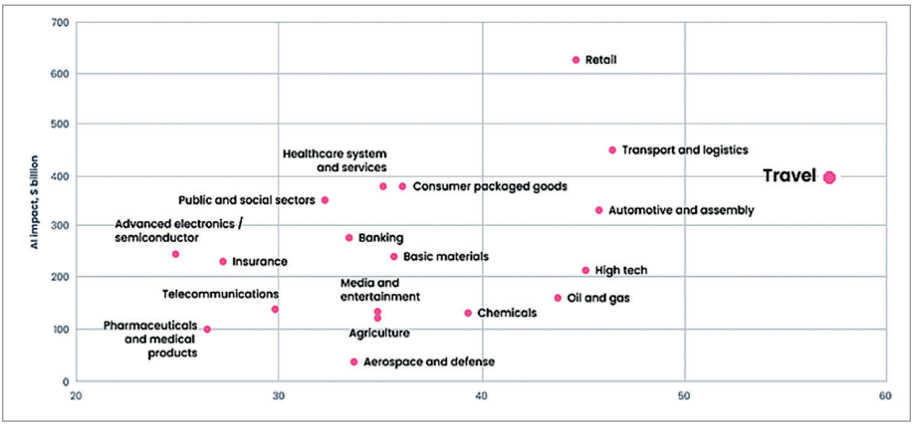

Fig. 1 Share of AI impact in total impact derived from analytics
Source: Shatalov (2024)

In their current paper, Collins, Ali and Yilmaz (2024) address the issue of artificial intelligence and its future implications for the tourism and hospitality sector. The authors bring an analytical view of advanced, deep artificial intelligence technologies and define up to seven technological solutions. Thanks to the advanced possibilities of information and communication technologies, it is possible to apply them in the future in order to get ahead of the competition, achieve a competitive advantage, reduce the business cost and reach new market segments.

Tab. 1 Possibilities of applying artificial intelligence in tourism

AI-BASED DL TECHNOLOGY (TYPE)	APPLICATION TO TOURISM
Convolutional Neural Networks CNN *An algorithm specifically designed for image processing and recognitions tasks* (Computer Vision)	Using CNN to recognize persons or prohibited objects at airports (secure registration at borders and check-ins), hotels and other tourist areas. It improves security controls and reduces the likelihood of risky situations. CNNs can analyze photos posted by tourists on platforms (e.g. TripAdvisor) and evaluate their emotional content (happy faces, satisfaction).
Style Transfer *A computer vision and graphics technique to combine the content of one image with the visual style of another* (Computer Vision, Graphics)	AI helps create personalized, dynamic and interactive experiences for tourists, increasing their satisfaction while improving the return on marketing investment.

AI-BASED DL TECHNOLOGY (TYPE)	APPLICATION TO TOURISM
Deep Learning Based Recomander system *An application that is based on multiple DL technologies, and uses an algorithm to suggest choises of interest on Big Data* (Ranking)	The concept of personalized itineraries involves the use of artificial intelligence (AI) to create tailor-made travel plans that consider travellers' preferences and needs. The concept of authenticated reviews uses AI to verify and ensure the authenticity of reviews about destinations, hotels, restaurants and other services in the tourism industry.
Generative Adversarial Network *A type of learning architecture that pits two neural networks against each other to generate new synthetic data in close resemblance to an existing data distribution* (Generative AI)	Personalized interactive adds - AI analyzes user data and advertising is adjusted based on user preferences. Tangibilization of future experiences - tourists can visualize and experience their planned experiences even before they take place.
Variational Autoencoder *An algorithm to generate new content while detecting and removing noise* (Generative AI)	Event simulations, accuracy in recreational programming - AI helps hotels plan activities such as wellness, sports programs or trips to match the profile of guests. AI can optimize recreational offers in cities (e.g. concerts, workshops, city tours) to attract more visitors.
Recurrent Neural Network *An algorithm that operates on sequential data to predict new outcomes.* (Sequential data processing)	Polylingual Tour - multilingual guide using AI allows tourists to receive information about destinations and attractions in their native language in real time. Universal Translations in tourism allow tourists to instantly and accurately translate signs, conversations or materials, increasing their comfort and independence while traveling. Accessible, Anti-Ableist Visitor Experiences - AI plays a key role in creating experiences that are inclusive for differently abled visitors, reducing barriers associated with disabilities or other barriers.

AI-BASED DL TECHNOLOGY (TYPE)	APPLICATION TO TOURISM
Graph Neural Networks (Solve problems related to graph-structured data)	Tourist Flow Prediction – AI is used to predict data to determine the number and behaviour of tourists in destinations. Tourist flow prediction is a powerful tool that enables effective planning, management and promotion in tourism with the help of AI. It makes it easier to cope with seasonal changes. It helps manage visitation in sensitive ecosystems and cultural sites to reduce negative environmental impact. Forecasts of the number of tourists allow more efficient planning of public transport, flights and other logistical elements. Forecasting the flow of tourists makes it possible to prepare for safety measures during major events or unforeseen situations such as natural disasters.

Source: processed and supplemented according to Collins, A., Ali, S.A., Yilmaz, S. (2024).

The author collective Collins, Ali and Yilmaz (2024) state that the means, possibilities and tools of artificial intelligence have literally invaded all spheres of the economy and are rapidly transforming the further development and direction of specific industries. Although artificial intelligence tools are quickly penetrating the tourism industry, this area is only poorly explored from a research perspective. The research study in question was undertaken to evaluate the application of artificial intelligence in hospitality and tourism. Among other things, the analysis revealed a new evaluation framework, through which there is a more effective perception of determinants affecting not only the acceptance, but also the integration of artificial intelligence tools in practice.

A slightly earlier published study by the scientific team of Huang et al. (2022) also dealt with the issue of deploying artificial intelligence in the field of tourism. The authors came to the conclusion that the inclination to accept means and tools of artificial intelligence in tourism and hospitality are differentiated in relation to the types of artificial intelligence. Chatbots, reservation systems, virtual agents, and search engines have a high tendency for acceptance and subsequent implementation. The application of artificial intelligence goes hand in hand with advancing innovations. The authors' empirical research confirms support for the continued implementation of various artificial intelligence technologies in hospitality services and in tourism as such.

In a short period of time, a number of scientific, professional and overview works dealing with the application of artificial intelligence have been published in scientific journals, scientific and conference proceedings, as well as in renowned

scientific databases. What still remains unexplored, which is and will have to be the subject of interest and research by experts, is the examination of the effectiveness of the functioning of the used applications and algorithms of artificial intelligence, as well as the variety of types of applications and multimodal data sets, note in their paper Doborjeh et al. (2022). The author team decided to evaluate the already implemented methods of artificial intelligence in hospitality services and tourism. They focused on choosing a destination, uncovering and evaluating patterns of consumer behaviour, and demand prediction possibilities. Deriving from these findings, they formulated topics for improving the quality of services provided to customers. Based on the performed analysis, the author's collective also formulates a proposal for the introduction of personalized modelling development through artificial intelligence as a platform for intelligent tourism.

A study, published by Pillai & Sivathanu (2020) explains how artificial intelligence and the integration of artificial intelligence technologies are influencing, transforming and will continue to reshape the tourism and hospitality industry in many dimensions. Their research highlights the potential challenges that entities operating in the tourism industry will have to deal with not only from a business perspective, but also from the point of view of regulatory authorities or customers. Miao & Yang (2023) recall the transformation of experiences from the perspective of tourism clients. Their paper conceptualizes the possible influence of artificial intelligence of the text-to-image type precisely on the sphere of experiences, starting with initial expectations, through perception and ending with memories of experiences.

The mentioned authors processed current trends in hospitality and tourism in international context, focusing on the integration and impact of artificial intelligence. However, the field of tourism does not avoid trends in the nearer, i.e. in Central European conditions for us. Several important strategic factors influencing the development of tourism also come to the fore. Pellešová and Vacha (2023), among others, reported on these trends and strategic factors in their earlier studies in this scientific periodical. Understanding current trends and the current position of tourism in interactional relationships also includes understanding culture, the interplay of semantic boundaries between the identity of a place, the image and reputation of a place (Matlovičová, 2024).

In recent years, sustainability has been significantly discussed on a daily basis in every sector of the economy, not excluding tourism. The international team of authors Khan, N. et al. (2024) focused their study on exploring the potential of deploying artificial intelligence methods and tools in the tourism industry, thus reflecting on the sustainability of business in this sector of the national economy. The implementation of artificial intelligence makes it possible to expand the effective way of managing resources and the entities themselves operating in the tourism industry. The strong development of technologies brings new

opportunities for deploying artificial intelligence in tourism operations as well. They have become more efficient and their activity more sustainable. Sustainability is manifested in these entities through development activities, more ecological operation, and environmental protection. The possibilities of deploying artificial intelligence are obvious, for example, in more efficient energy management, waste management, optimization of transport solutions and sustainable management of resources. All these steps lead to higher protection of the environment and better management of natural resources. The deployment of artificial intelligence also helps to facilitate and improve the provision of experiences, but with a higher degree of greening through the implementation of virtual assistants and recommended systems. Naturally, the development and deployment of artificial intelligence must also consider the aspect of personal data protection, privacy protection and other aspects of information security. The authors support the inclusive implementation of artificial intelligence and indicate possible challenges that will need to be faced mainly in developing areas.

The tools and means of artificial intelligence bring new opportunities, and today artificial intelligence itself represents a very effective tool for increasing efficiency in the tourism industry. Another group of researchers, Salameh Alkhazaleh et al (2024) highlight how artificial intelligence offers numerous innovative solutions applicable by various businesses within the tourism industry. According to them, it is possible to include, for example, intelligent systems used by travel agencies or companies providing transport services. This collective of authors states that thanks to artificial intelligence, the tourism industry is also undergoing a transformation. This creates new possibilities, development opportunities and also a change in consumer habits and interaction with individual destinations. The important question of how it is possible or appropriate to adapt to such a dynamic revolution of advanced technologies, when machines have already begun to achieve a higher level of intelligence than humans. In our view, this issue will encompass not only technological and social dimension but also philosophical and ethical challenges.

Modern solutions related to artificial intelligence can be attributed primarily to those with technical and natural science education, who were most responsible for the establishment and subsequent development of start-ups. The implementation of innovations and new solutions has introduced substantial resources, including financial investments to business entities, according to Filieri et al. (2021). Among the European start-ups, it is possible to mark the capital cities of important tourist destinations, which include Spain, France, the United Kingdom, as their pin. Artificial intelligence solutions primarily focus on processing large data sets, facilitating tasks such as data segmentation, automation of marketing activities, and similar activities.

In the context of the conclusions of the above-mentioned authors, a pair of foreign experts Doğan and Niyet (2024) state in their paper that thanks to the

possibilities of artificial intelligence, decisions based on large set of data become significantly more effective, which is manifested, for example, in the improvement and efficiency of the marketing strategies of tourism entities. They consider the most valuable fact to be the contribution of artificial intelligence in the ability to create personalized recommendations. Not only accommodation facilities, such as hotels, guesthouses, but also travel agencies and companies providing transport services help potential clients through chatbots in choosing or fulfilling their requirements. For example, at airports, modern facial recognition technology can immediately and accurately identify clients, which contributes to the smoothness and safety of operations. By collecting data on the client's previous travel history or preferences, artificial intelligence can propose customized destinations for the client, accompanied by catering and accommodation services. These conveniences will undoubtedly contribute to a higher level of travel experience. Tourism entities often encounter the problem of operational efficiency. This is another area where artificial intelligence can be utilized, as it is possible to optimize specific processes and service delivery.

Also Zhang et al. (2023) emphasize that chatbot is currently one of the most frequently used artificial intelligence tools in tourism services. It is a human-computer interaction. They consider the interest or willingness of customers to continue using chatbots to be an unexplored area. As part of their research, they developed an integrated model of factors that demonstrably influence customers' continued interest in using chatbots. Their research revealed a positive correlation in relation to expected performance, habits, personalization, social influence and anthropomorphism. Negative determinants according to research are the privacy and time risk. From a gender perspective, only two differences were detected, while no other distinction between men and women were observed.

Hsu et al. (2024) focused in their study on the possibilities of defining the benefits of artificial intelligence in the context of tourism development. Their approach represents a balanced concept defining the positive and negative sides of using artificial intelligence tools. According to their research, generative artificial intelligence can contribute to increasing business performance and enhancing the client's tourist experience. On the other hand, they consider the accuracy and quality of data to be a weakness of generative artificial intelligence. A collective of authors proposed a generative artificial intelligence concept with a special focus on tourism and multi-party datasets. Preliminary research points to the need to fine-tune the large language model through credible and specific documents. The new generative concept of artificial intelligence is capable of delivering timely, clear and accurate results based on the available data base.

The term artificial intelligence comes from computer science, but in a short time it has penetrated basically every sphere of life and science. This fact caused an increased interest in the academic and research spheres in monitoring the

penetration of artificial intelligence into individual spheres. The deployment of artificial intelligence brings new possibilities and new forms of solving a wide range of problems. This is also the case in the field of tourism. Kırtıl & Aşkun (2021) conducted bibliometric research on a sample of 102 scientific papers indexed in the world scientific database Scopus. Their bibliometric research activity was the first in the field of tourism and is still a suitable starting point for further research. Their activity led to the definition of key determinants. The high interest in researching artificial intelligence in the tourism industry results in high citation of such papers.

Another study of a wider range of experts by Kong et al. (2023) aimed to assess the current progress in artificial intelligence research, specifically within the fields of hospitality and tourism. Expert terms, trends in artificial intelligence research, keywords, content focus became the key content points. The study covered the period starting from 1991 with the identification of an increasing trend and a break in 2018. Since then, there has been a significant increase in interest and publications with the given issue. The collective of authors states that artificial intelligence has become the centre of interest of researchers and scientists. They also defined four thematic areas with the greatest degree of interest: the appearance of new technological solutions, the acceptance of technological innovation, the perception of tourism clients and the prediction of trends. While in the first period the interest was concentrating on the possibilities of artificial intelligence technologies, currently, according to the authors, the interest is focusing on the customer acceptance of artificial intelligence and their attitude towards it.

OBJECTIVES

The aim of this paper is to provide an overview of the use of artificial intelligence in tourism and its potential contribution to the sector. Based on the Global AI Index values and its individual dimensions, we will analyse the differences between countries and identify clusters of countries with similar characteristics. Based on the previous overview of AI applications in tourism, we will suggest specific AI steps that similar countries in each cluster should take to increase the importance of tourism in their economies through the effective use of AI technologies.

DATA AND METHODS

Methodical background of the issue was supposed to be based on current and appropriate methodological procedures. We followed the primary task, which was to evaluate the level of artificial intelligence. In order to be able to ensure an objective and compact analytical view of the investigated issue, it was necessary to apply a suitable metric recognized by the global professional community. In our case, we applied The Global AI Index by Tortoise Media (https://www.tortoisemedia.com/intelligence/global-ai/#data), which, following numerous

expert discussions across Europe and globally, has become well-established and is considered by experts as a suitable tool for quantification. The acceptance of this index for quantification is supported by the fact that it measures data for a sample of up to 83 countries that invest intensively in artificial intelligence. The evaluation is carried out on the basis of not only investments, but also innovations in constantly improving artificial intelligence technologies. The evaluation, using the global index of artificial intelligence is based on the evaluation and comparative evaluation of countries according to their ability to implement artificial intelligence, or the capacity to continuously innovate already existing artificial intelligence. The company Tortoise Media can be found behind the creation of the index, which constantly monitors the development of artificial intelligence on a global scale, both at the level of various countries and at the global level, and based on the collected data, develops professional expertise and analyses. It thus identifies key development factors. The composition of the index is based on the coexistence of several criteria used to quantify the country's capabilities in the field of artificial intelligence. In total, it can be stated that The Global AI Index is constructed using 122 indicators sourced from both public and private data. There were a total of 24 of these sources and 83 countries were involved. The input sources are made up of 3 supporting pillars (talent, research, government strategy), which are distributed into 7 supporting pillars.

The first pillar is implementation. Within this pillar we distinguish another 3 supporting pillars, which are talent, infrastructure and operating environment. The supporting pillar of talent integrates the availability of a qualified workforce capable of solving the issue of artificial intelligence. The second supporting pillar, which is infrastructure, focuses on the field of semiconductor production and also on the assessment of modern computer infrastructure in terms of its scope. The last supporting pillar in the first supporting pillar is represented by the operating environment, which deals with the regulatory context and monitors the level of public opinion about artificial intelligence. Innovation is defined as the second main pillar, which is formed by two supporting pillars: research and development. Research focuses on quantifying the quality and also the availability of volume not only of academic research, but also of research in industry. Development explores the possibilities of applying the availability of artificial intelligence technologies in various fields, including patents, and also explores the creation of new artificial intelligence models.

The last main pillar is investment. It is divided into two supporting pillars, which are Government Strategy and Commercial. The first supporting pillar quantifies the amount of government commitments in the area of artificial intelligence, including the amount of funds spent on fulfilling these commitments and implementing the national strategy in the area of investments in artificial intelligence. Commercial tracks start-up business entities and quantifies the level of their activity, monitors

and quantifies the level of commercial initiatives and the volume of private investments in the field of artificial intelligence. A good feature of the global AI index is the fact that it includes not only the core factors, but also additional components such as scientific publications related to artificial intelligence, the volume of patents, investments made in artificial intelligence, and also in the educational system focused on the field of artificial intelligence. The above helps to understand where the development of artificial intelligence is currently heading.

This paper is addressing the tourism industry and applies the indicator Tourism direct GDP as a proportion of total GDP, which is expressed in relative terms and was published by the World Tourism Organization (UNWTO) for the year 2019 (acronym Y2019). The goal of UNWTO is to provide a helping hand to member countries in the field of statistics, research and also technical assistance with a focus on activating initiatives aimed at improving the contribution of tourism.

Currently, as of the end of October 2024, data for only three countries - Greece, the Netherlands and Portugal – are available for the evaluated period of 2022. The UNWTO points out that the overall data is an estimate provided by the organisation. For the stated reason, we methodologically considered it objectively to use data from 2019 for evaluation purposes, because in this period the data were not affected by the impact of the pandemic. In the case of the two selected countries, which are Bulgaria and Cyprus, however, the data cannot be determined, as it is unavailable. In order to clarify our methodological procedure, we consider it necessary to state the reasons for the application of the global index of artificial intelligence for the year 2024 (or for the year 2023) and the share of tourism in the creation of the gross domestic product for the year 2019.

We have chosen the share of tourism in GDP for 2019 as a benchmark for several reasons. First of all, 2019 represents the last year before the outbreak of the COVID-19 pandemic, which had a significant impact on global tourism. Pandemic constraints such as lockdowns, travel restrictions, and reduced travel demand have fundamentally disrupted the normal functioning of the sector and caused sharp declines in tourism revenues.

Although tourism has gradually recovered in recent years, it still shows lingering effects of the pandemic, which could distort the results of the analysis. By using data from 2019, we get a more relevant picture of the importance of tourism in the economies of each country under normal conditions, without the temporary effects of the crisis situation. This approach allows a more precise evaluation of the long-term relationships between the level of AI development and the importance of tourism in national economies.

This algorithm or the combination allows us to include not only the latest but also stable data on artificial intelligence in our analyses. This subsequently leads to more accurate results of the performed analysis without the distorting influence of the pandemic situation.

An important method used in our evaluation is PCA Principal Component Analysis, which according to several experts (Blighe, K., Lun, A., 2021; Kassambara, A., 2017) serves not only to summarize, but also to visualize the information obtained for a set of data, which were observed and their description is possible based on the identified correlations between quantitative variables. We perform the quantification of information from the dataset through total variance. PCA principal component analysis has the advantage, among other things, that it can reduce the breadth of multivariate data to a small number of principal components, for example two or three. These can then be visualized graphically. In our case, we will use a biplot for graphic visualization. We consider the biplot suitable not only for the presentation of observations, but also for the presentation of variable matrices of multidimensional data in the same graph. This makes the visualisation more compact and comprehensive.

Hierarchical cluster analysis was applied, enabling the identification of mutual relationships and patterns within the collected data set. In cluster analysis, we use Euclidean distance to measure the similarity or dissimilarity between objects in a multidimensional space. Performing cluster analysis requires evaluation and assessment of the quality of the clustering results. Cluster validation is the process of evaluating the quality and stability of clusters obtained by cluster analysis. It involves various methods to verify that the identified clusters are well separated, homogeneous and interpretable. The selection of the clustering method can be done by using the agglomeration coefficient. Higher values of the coefficient are attributed to better clustering method.

Internal clustering validation evaluates the quality of clusters based on internal cohesion and separation. We used Dunn's index, which compares the smallest distance between clusters with the largest distance between points within a cluster. If the data set contains compact and well-separated clusters, the diameter of the clusters is expected to be small and the distance between the clusters is expected to be large. Thus, Dunn index should be maximized (Kassambara, 2017).

The stability of the clusters is necessary to trust the results of hierarchical clustering. Bootstrap validation provides an objective way to verify whether clusters are robust or may be the result of random fluctuations in the data. We used the pvclust package to validate the robustness of hierarchical clustering using bootstrap resampling. We compute the approximately unbiased (AU) probability values (p-values) by multiscale bootstrap resampling (Kassambara, 2017). The p-values are reported as percentages. Clusters with AU greater than 95% are very stable clusters, likely representing real patterns in the data. Clusters with AU between 90 and 95% are relatively stable, but may change with different sampling. Clusters with AU less than 90% are uncertain clusters, they may be artifacts or random clusters. If many nodes in the dendrogram have low AU p-values (<90%), the clustering is not very reliable and should be re-evaluated.

The analytical calculations performed by us were carried out in the R programming environment, which allows not only scientific calculations, but also the subsequent visualization of data through suitable software tools.

RESULTS AND DISCUSSION

The decisive part of the presented article is the results part connected with the discussion, which contains the essential findings based on the performed analysis. As a first step, we present the results of the descriptive statistics calculations, which are presented in Table 2 below.

Tab. 2 Descriptive statistics

ACRONYM	AVERAGE	MEDIAN	MINIMUM	MAXIMUM	STANDARD DEVIATION
Overall	13.8	13.0	5.0	28.0	5.7
Talent	13.3	11.0	5.0	35.0	7.3
Infrastructure	24.0	22.0	16.0	40.0	6.1
OperEnviro	66.4	67.0	27.0	100.0	15.3
Research	6.0	5.0	1.0	18.0	4.2
Development	6.3	5.0	0.0	31.0	6.9
GoverStrat	31.0	31.0	0.0	66.0	18.0
Commercial	8.6	7.0	1.0	19.0	5.0
Y2019	4.5	4.0	1.2	11.8	2.3

Source: own processing using software

Table 2 presents average values for various individual indicators. It is clear that OperEnviro with 66.4 points achieves the highest value, which indicates a favorable operating environment. Two categories with a small difference, which show the lowest values, were placed on the exact opposite pole. They are Research (with a score of 6.0) and Development (with a score of 6.3). The results signal weaker performance in the field of research and development. Regarding the assessment of other values, it can be emphasised that two categories, GoverStrat (with a score of 31.0) and Infrastructure (with a score of 24.0), placed approximately in the middle of the values. These can be rated as slightly better. The remaining two categories Talent (with score of 13.3) and Commercial (with a score of 8.6) can be considered relatively weaker.

In the case of the main components, it can be stated that they correspond to a linear combination of the original variables. The question was also to determination the variance. Each principal component was quantified by the eigenvalue of the correlation matrix.

There are several criteria when choosing the number of main components. The starting point from the cumulative percentage of the total variance can be considered the leading criterion, since it is captured by the main components. Setting the value at the level of approximately 80% is considered a scientific standard. In the implemented case, 74.26% of the variability is explained by two main components. Based on this, we determined the number of main components to be 2. Another starting criterion is the so-called Kaiser's rule. The principle of Kaiser's rule says that we keep only those main components whose variances exceed 1. In practice, this means that we keep those for which the eigenvalues are higher than 1. In our case, the first two eigenvalues are 5.45 and 1.23, which meet this condition. It means that we will continue to work with the first two main components. Table 3 presents the calculated values of the eigenvalue of the correlation matrix with the proportion of explained variance.

Tab. 3 Values of the eigenvalue of the correlation matrix and the proportion of explained variance

	eigenvalue	variance. percent	cumulative. variance. percent
Dim.1	5.449809	60.55344	60.55344
Dim.2	1.233167	13.70185	74.25529
Dim.3	0.840272	9.33636	83.59165
Dim.4	0.559841	6.220453	89.81211
Dim.5	0.369400	4.104443	93.91655
Dim.6	0.337587	3.750966	97.66751
Dim.7	0.164369	1.826326	99.49384
Dim.8	0.044665	0.496282	99.99012
Dim.9	0.000889	0.009879	100.00000

Source: own processing using software

In the next part of our analysis, we will present the results of subsequent calculations through tabular support. The tables contain the obtained results of testing the significance of the correlation coefficients between the variables and the defined first two main components. It is clear that each variable has a statistically significant relationship with at least one principal component, therefore no variable needs to be excluded from further analyses.

Tab. 4 Link between the variable and the 1st principal component

acronyme	correlation	p. value
Overall	0.9919236	3.93E-22
Talent	0.9380322	4.53E-12
Research	0.9370864	5.37E-12
Infrastructure	0.8336408	2.28E-07
Development	0.8173366	6.14E-07
GoverStrat	0.8050674	1.22E-06
OperEnviro	0.5777242	2.49E-03
Commercial	0.5567244	3.85E-03

Source: own processing using software

PC2 as a defined second component shows a strong relationship with the variables Y2019 and Commercial. The found correlation relationship between Y2019 (tourism contribution to GDP in 2019) and PC2 is 0.750 with a significantly significant p-value of 1.55E-05, which underlines that there is a substantial relationship. The situation is similar for the variable Commercial, which reflects the level of the Commercial Ecosystem. There is a correlation of 0.659 with PC2 at a p-value of 3.40E-04. This finding demonstrates a strong and significant association (Table 5). The obtained analytical results indicate that these two variables have a key role in defining the second dimension of variance in the data.

Tab. 5 Link between the variable and the 2nd principal component

	correlation	p. value
Y2019	0.7504735	1.55E-05
Commercial	0.6590504	3.40E-04

Source: own processing using software

Biplot illustrates the results of a principal components analysis (PCA), where points represent the individual countries, and blue arrows indicate the variables, which identify the main drivers of variability in the data. The first principal component (Dim1) explains 60.6% of the variability, and the second principal component (Dim2) explains a further 13.7%.

The biplot illustrates that countries such as France (FR) and Germany (DE) are significantly to the right, indicating that they score high in AI-related areas such as research, talent, infrastructure and government strategy. This suggests that these countries have a well-developed AI environment, supported by government investment and a strong research base.

In contrast, countries such as Latvia (LV), Slovakia (SK) and Romania (RO) are on the left-hand side, indicating lower values in the AI index dimensions. This may be a consequence of less availability of AI talent, weaker infrastructure or lower investment in AI research and commercialisation.

The Y2019 variable (tourism contribution to GDP) has an upward slope , indicating that it is more strongly associated with the second principal component (Dim2). This suggests that countries higher up the graph, such as Croatia (HR) or Greece (EL), have a higher share of tourism in GDP.

AI index dimensions such as Talent, Research, Development and Government Strategy are oriented in a similar direction, suggesting that countries with high scores in one of these areas often score well in the other AI factors. Specifically, countries such as the Netherlands (NL), Sweden (SE) and Denmark (DK) have higher scores in the talent and infrastructure dimensions, which may indicate a strong technology base supporting AI development.

The Commercial dimension, which reflects startup activity and investment in AI entrepreneurship, is transport-oriented. This suggests that countries that are in this direction of the chart have a stronger business environment for AI innovation.

Overall, the biplot reveals two main trends: one group of countries is characterised by a strong focus on AI and technological development, while the other group has a higher share of tourism in GDP and a less developed AI environment. This perspective allows identifying patterns across countries and understanding how AI factors correlate with economic variables such as tourism's share of GDP.

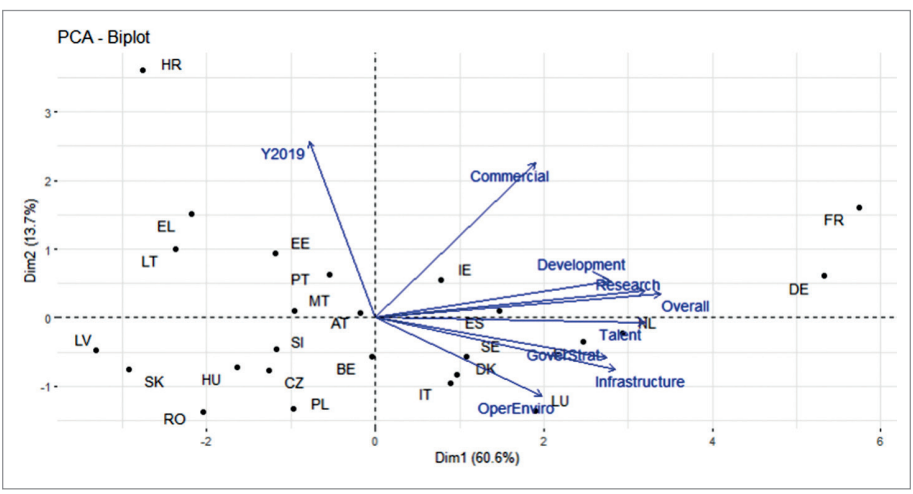

Fig. 2 Biplot

Source: own processing using software

In the next step, we proceeded to cluster analysis. The average linkage method is the best according to the agglomeration coefficient because it better preserves the hierarchical consistency in the clustering. Internal clustering validation evaluates the quality of clusters based on internal consistency and separation The single linkage and average linkage methods produce the best separated clusters according to Dunn index. Ward.D2 is the weakest, which means it may produce more compact but less separated clusters. For the above reasons, we used the average linkage clustering method. It produces balanced clusters that are neither too stretched nor too compact.

Tab. 6 Choosing of clustering method

Method	ward.D2	complete	single	average
Dunn index	0.30198	0.306598	0.531261	0.531261
Agglomerative coefficient	0.65712	0.747266	0.711874	0.82133

Source: own processing using software

Next, we proceeded to compute hierarchical clustering and validate the stability of the clusters.

In the dendrogram (Fig. 3) we cansee that the approximately unbiased p-value for the cluster of the countries Czechia, Hungary, Poland and Romania is 98 percent, i.e. the cluster is stable and considered reliable. After adding Slovakia and Latvia to the list, the cluster is relatively stable (the value of approximately unbiased p-value is 93 percent) and we can consider the clustering result as reliable.

The first cluster comprises Central and Eastern European countries with a relatively low contribution of tourism to GDP (Y2019), ranging from around 2.2% to 4.8%. The value of the overall AI index (Overall) is relatively low, ranging between 5 (Latvia) and 11 (Czech Republic and Poland).

In terms of AI talent, these countries tend to have poor to average scores, with Poland (11) and the Czech Republic (10) having the highest scores, while Romania (5), Latvia (5) and Slovakia (6) have lower scores. Infrastructure is relatively balanced, ranging between 18 and 23 points, indicating stable but not highly developed access to computing and digital capabilities.

The regulatory environment and public opinion on AI (OperEnviro) are slightly below average in these countries, with values oscillating between 47 (Czech Republic) and 66 (Romania). Research activity (Research) is very low, with most countries scoring between 1 and 4, the exception being Romania (7).

The development of basic AI platforms (Development) is poorly developed in this cluster, with some countries (Slovakia, Latvia) showing virtually no activity in this area. Government strategy (GoverStrat) is variable - the Czech Republic (45) and Poland (31) have relatively high values, while Slovakia and Latvia have zero scores, indicating the absence of a strong AI strategy.

On Commercial, countries have low scores, mostly between 1 (Romania, Latvia) and 5 (Hungary). This cluster thus represents a region with limited development of the AI ecosystem, yet notable differences exist between countries, especially regarding government strategies and the regulatory environment.

Countries in the first cluster, such as the Czech Republic, Hungary, Poland, Romania, Slovakia and Latvia, could significantly boost tourism development through AI if they focus on strengthening key dimensions of the AI ecosystem.

One of the most important factors is the development of talent(Talent) in the field of AI. Upskilling professionals and promoting education in this area would enable the creation of intelligent recommendation systems, chatbots and personalised tourist experiences. For this, a modern digital infrastructure is also essential. Investment in high-speed internet, cloud services and computing capacity would improve the availability of AI solutions for hotels, airports and tourist attractions.

Research is also an important part of promoting AI in tourism. If First Cluster countries invested more in research projects on AI in tourism, they could manage tourist flows more effectively, anticipate seasonal trends and protect cultural sites from an over-abundance of visitors. In addition to research, funding is also needed to develop AI platforms that would help optimise hotel and service prices according to current demand and enable efficient capacity management.

Supporting startups and investing in AI solutions in the tourism sector would create new opportunities for smart booking systems, digital guides and innovative services that could attract more tourists. Governments should therefore develop a strategy to effectively link AI and tourism, for example through subsidies or legislative measures to facilitate the adoption of these technologies.

If countries strengthen these dimensions, they could increase the efficiency of tourism, offer visitors more personalised experiences and increase tourism revenues. At the same time, AI innovations would help improve the competitiveness of destinations and attract modern tourists who expect smart and digital services.

In the second cluster are Ireland, Sweden, Belgium, Denmark. The approximate unbiased p-value is 96 percent, i.e. the cluster is stable (more than 95 percent) and considered reliable. The second cluster includes the economically developed countries of Western and Northern Europe. These countries have a strong position in applying AI, but their tourism contribution to GDP (Y2019) is relatively low, ranging between 1.86 percent (Belgium) and 4.76 percent (Ireland).

The overall AI index (Overall) is significantly higher in this cluster than in the first cluster, with values ranging from 14 (Belgium) to 16 (Ireland, Sweden and Denmark). These countries also have a strong talent pool, with Sweden and Denmark having the highest values in this area (17), indicating a high availability of skilled AI professionals.

Infrastructure is at a very good level, with scores ranging from 20 (Belgium) to 26 (Ireland, Sweden), indicating the robust digital and technological capabilities needed to develop AI solutions. The regulatory environment and public opinion on AI (OperEnviro) are at a high level in this cluster, with Sweden scoring as high as 88, indicating favourable legislative conditions for AI implementation.

Research activity (Research) is significantly higher compared to the first cluster, with Sweden standing out the most (8), while the other countries are between 5 (Ireland) and 7 (Denmark). The development of AI platforms and algorithms (Development) is moderately developed in these countries, with Ireland scoring highest (14), while the other countries have lower scores (5 to 6).

Governments in these countries show varying levels of commitment to AI (GoverStrat), with Denmark (44) and Ireland (31) investing more in AI strategies, while Belgium (27) and Sweden (23) have slightly lower levels of support. Commercial use of AI is relatively strong in this cluster, with Ireland and Sweden scoring highest (12).

Overall, these countries are advanced economies with good technological backgrounds and favourable conditions for AI R&D. They have the advantage of high quality talent and infrastructure, but tourism plays less significant role in their economies. If they wanted to increase the use of AI in tourism, they could focus on leveraging their technological potential to create innovative solutions such as smart travel apps, automated booking systems and tourist flow analytics.

The countries in the second cluster - Ireland, Sweden, Belgium and Denmark - already have a well-developed AI ecosystem, but tourism plays a smaller role in their economies. If they want to use AI to boost tourism, they should focus on strengthening specific dimensions that can link their technological capabilities to the needs of the tourism sector.

One of the key areas for improvement is the commercialisation of AI (Commercial). Although these countries have a solid business environment for AI startups, they should encourage dedicated investment in AI solutions for tourism. This could lead to the development of innovative booking platforms, smart destinations and personalized AI-based travel guides.

Another important step is to increase government support (GoverStrat) for AI applications in tourism. Countries such as Denmark and Ireland already have relatively strong AI strategies, but governments need to create specific programmes to fund the development of smart tourism solutions, for example for automated visa processing, digital tourist assistants and smart crowd management systems in popular locations.

These countries also have highly skilled AI talent (Talent), but it is important to incentivise professionals to get involved in developing tourism applications. Dedicated hackathons, research grants and partnerships between universities and the private sector can be organised to develop AI solutions for tourism.

Given the strong technological infrastructure (Infrastructure) of these countries, it would be beneficial to invest in the development of predictive analytical tools to optimise tourist flows, dynamic pricing of accommodation and transport or modelling of demand in different seasons. This would help to manage capacity in tourism more efficiently and at the same time increase revenues in the sector.

The overall expected impact of these measures would be to increase competitiveness in tourism, improve the quality of services and attract more tourists who value digital innovation. Linking AI to tourism could thus strengthen the economies of these countries while improving the visitor experience.

The approximate unbiased p-value for the third cluster is 99 percent, i.e. the cluster is stable (more than 95 percent) and considered reliable. It includes countries such as Portugal, Malta, Slovenia, Austria and Estonia, which are characterised by a medium contribution of tourism to GDP (Y2019), ranging from 5.33 per cent (Austria) to 8.1 per cent (Portugal). These countries have a relatively balanced level of AI ecosystem development, but with some variation across dimensions.

The overall Global AI Index (Overall) score ranges from 11 (Slovenia) to 13 (Portugal, Austria), indicating a slightly above average position in AI in the global context. The availability of AI talent (Talent) is moderately developed in this cluster, with Austria scoring the highest (15), while Malta (6) and Slovenia (8) show weaker levels of professional capacity in this area.

Infrastructure is relatively homogeneous in these countries, with values between 19 (Estonia) and 22 (Portugal, Slovenia, Austria), indicating a solid technological background for the development of AI applications. The regulatory environment and public opinion on AI (OperEnviro) is highly favourable in some countries, especially in Portugal (84) and Slovenia (76), which may support the development of AI solutions in tourism. In contrast, Estonia (59) and Austria (61) have lower scores in this area.

AI research (Research) shows large differences, with Austria (9) being the leader of the group in this area, while Malta (3) and Portugal, Estonia and Slovenia (4-5) have lower levels of publication activity and academic research in AI.

A significant gap in some countries is the development of AI platforms and algorithms (Development) - Slovenia and Estonia have a value of 0, which means that there is no significant support for the creation of AI technologies in these countries. In contrast, Malta (9) and Portugal (8) have a relatively strong development base, which allows them to create and implement new AI solutions.

The government's AI strategy (GoverStrat) differs significantly in this cluster. Malta (35) has the highest score, followed by Austria (33) and Estonia (29), indicating that these governments are actively supporting AI initiatives. In contrast, Slovenia (28) and Portugal (24) have lower levels of government commitment to AI.

Commercial use of AI (Commercial) is moderately developed in this group - Estonia (13) stands out with the highest score, indicating a strong link between

AI and the business environment, while the other countries score between 5 (Slovenia) and 7 (Portugal).

Overall, these countries represent technologically advanced economies with a stable infrastructure and a moderately developed AI ecosystem. Their strong regulatory environments and government support can be the basis for more effective integration of AI into tourism. If these countries would like to strengthen the use of AI in tourism, they should focus on developing talent, increasing research activity and supporting startups focused on AI solutions in travel services.

Countries such as Malta, Estonia and Slovenia, which have lower values in the availability of AI talent, would benefit from investing in education and training programmes. Collaboration between academic institutions and technology companies offering professional courses and hands-on training in AI applied to tourism could contribute to this. Upskilling professionals would allow AI to be used more effectively to develop personalised tourist experiences, chat bots for customer support and optimisation of tourist itineraries.

Countries such as Estonia and Austria, which have a stronger commercial environment, should focus their attention on supporting startups and entrepreneurial initiatives focused on AI solutions for tourism. Investing in innovative projects such as smart booking platforms, dynamic pricing or systems for predicting tourists' preferences could significantly streamline the tourism sector. This could enable new technologies and applications to emerge that would improve the customer experience, reduce operational costs and increase the competitiveness of tourist destinations.

Countries such as Malta and Austria with relatively high values in terms of government support should continue to develop national strategies that promote AI in tourism. This could include creating a legislative framework for the safe and ethical use of AI, as well as providing grants and financial incentives for initiatives that integrate AI into tourism services.

Given the growing emphasis on sustainability, countries in this cluster could use AI to develop solutions that help optimise tourism flows, minimise the negative environmental impact of mass tourism and improve resource efficiency. Intelligent systems could monitor visitor arrivals, analyse energy and water consumption in tourist facilities and prevent infrastructure congestion. These solutions would help to achieve sustainability in tourism, reducing environmental impact while providing tourists with a quality and efficient experience.

The approximate unbiased p-value for the fourth cluster is 90 percent. The cluster is relatively stable and the clustering result can be considered as trustworthy. The fourth cluster includes countries that show a strong presence in AI and a relatively higher contribution of tourism to GDP (Y2019). Countries in this cluster, namely France and Germany, show excellent performance in most dimensions of the Global AI Index, indicating a mature and stable AI ecosystem

that has the potential to significantly boost tourism development. France (25) and Germany (35) score very strongly in the area of Talent Availability (Talent). These countries have a rich base of AI experts, which means they are able to develop sophisticated technologies to support a variety of industries, including tourism. The significant presence of talented experts to develop, implement and optimise AI applications provides a strong foundation for innovation in the tourism sector. Germany (32) and France (31) also show excellence in Infrastructure. This means that both countries have a stable and modern infrastructure that includes high-speed internet, energy reliability and access to computing capacity, including supercomputers, which is key for the development and application of demanding AI technologies. High quality infrastructure also enables faster implementation and wider deployment of AI solutions in tourism.

In the area of regulatory environment (OperEnviro), both countries score high, Germany (83) and France (70). This indicates that they have a stable and favourable legislative framework for the uptake and implementation of AI. There are clear regulations on ethics, privacy and security, which is essential to promote user confidence in the uptake of AI in various sectors, including tourism.

In the area of Research, these countries also score highly, with Germany (16) and France (18) leading the way in the number of research publications, patents and academic achievements in the field of AI. The high research potential of these countries enables the development of innovative AI solutions that can improve the quality and efficiency of tourism services, as well as contribute to sustainability and the development of new technologies in tourism.

In the area of Development, both countries are relatively strong, with Germany (14) and France (31) investing in the development and testing of new AI algorithms and platforms. A strong focus on development enables the creation of customised and advanced technologies that can improve the forecasting of tourism trends, optimise visitor arrivals and enhance the customer experience in real time.

France (59) and Germany (59) consistently show excellent government engagement (GoverStrat) in AI. Both countries have developed national strategies and policies to support AI research and implementation, which includes funding for innovation projects, support for startups, and investment in AI infrastructure development. Strong government support for AI creates a favourable environment for the commercialisation and wider deployment of these technologies, including their application in tourism.

In Commercial, values are strong in both countries, with Germany (17) and France (19). They are in the top quartile. This suggests that these countries have high levels of commercialisation of AI innovation, including startups, entrepreneurial initiatives and investment in commercial products. The high level of commercial development enables the use of AI in practical applications that can

streamline the operation and management of tourism services, as well as increase the competitiveness of destinations.

The fourth cluster of countries is characterised by a strong and mature AI ecosystem. They have a robust infrastructure, high availability of talent, a favorable regulatory environment, and strong government support. These countries can leverage their research and development capabilities to create innovative AI solutions that could improve the quality of tourism, optimize tourism flows, contribute to sustainability, and enhance the overall tourist experience. High commercial engagement suggests that innovative AI technologies can be rapidly implemented in tourism services, which would boost tourism competitiveness and growth.

The approximate unbiased p-value for the fifth cluster is 90 percent. The cluster is relatively stable and the clustering result can be considered as trustworthy. The fifth cluster contains Spain and Italy, countries with a relatively strong position in AI and tourism's contribution to GDP (Y2019).

While these countries are not complete leaders in each area, they still show high potential for the use of AI in various sectors, including tourism. Both Spain (17) and Italy (16) score decently in the Talent domain, indicating the presence of skilled AI professionals, albeit not as strongly as in some other countries. Nevertheless, there is potential in these countries to develop and attract more AI professionals who can support the development of advanced tourism solutions such as smart booking systems, personalised offers or optimisation of tourism flows. The development of talent can lead to the creation of innovative technologies that will improve tourism experiences and operations in the tourism sector.

Spain (26) and Italy (23) score moderately in Infrastructure. Although both countries have well-developed infrastructure, their values show that there may be opportunities to improve the availability of high-speed internet and energy capacity, which are needed to effectively implement AI applications in tourism. Stronger infrastructure could facilitate the development of advanced AI solutions that enable tourists to access smart services and information in real time.

Improved infrastructure can enable faster and broader development of AI applications in tourism, including automated recommendations, predictive analytics, and more efficient bookings.

Spain (74) and Italy (100) score very high on the regulatory environment (OperEnviro). Italy, in particular, excels in its values, indicating strong legal frameworks and policy support to implement and regulate AI solutions. Spain also has very good conditions for the deployment of AI technologies, which is crucial to promote public trust and transparency in AI applications in tourism, such as services based on the analysis of tourist data and preferences. A strong regulatory environment can foster trust in AI solutions in tourism and ensure that new applications are ethical and safe for tourists.

Both Spain (6) and Italy (7) have Research dimension values in the third quartile. Research activities and strengthening innovation in AI could accelerate the development of new solutions for tourism, such as analytics tools to analyse tourist behaviour, smart bookings and personalised marketing campaigns. The research potential can foster the emergence of innovative AI solutions that will improve the prediction of tourism trends, optimisation of accommodation facilities and services.

In the area of Development, Spain scores 10, indicating a moderately active presence in this area, while Italy (2) has a lower level of development compared to other countries. This means that while there is room for the creation of new applications and platforms, these countries can still improve their capabilities in this area to match the leaders in AI.

Both countries score strongly on government strategy ((GoverStrat)). Spain 66, Italy 53, indicating that they have clear plans and support from the government to develop AI and its application in various sectors, including tourism. Strong government support may lead to a greater focus on innovation in tourism and the implementation of AI technologies. Improved government support can accelerate

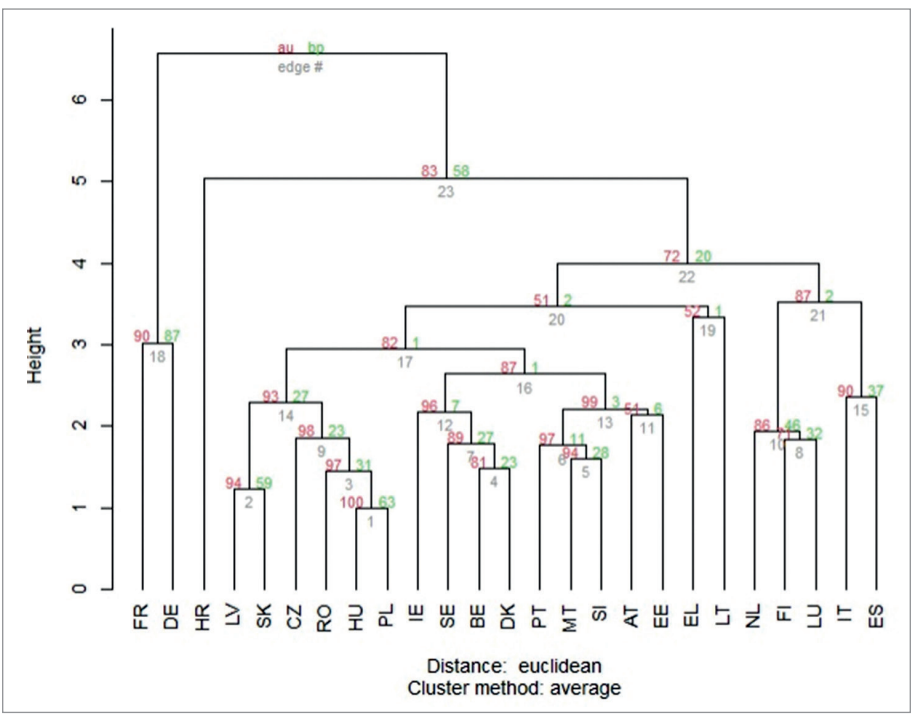

Fig. 3 Cluster dendrogram with p-values
Source: own processing using software

the deployment of innovative AI solutions in tourism, such as smart guide systems or optimised marketing campaigns.

In Commercial, Spain (7) and Italy (5) show values on the borderline of the first and second quartile. This suggests that there is room for further development and commercialisation of AI solutions in the tourism sector. Both countries can support the emergence of startups and entrepreneurial initiatives that focus on innovation in tourism through AI technologies. Greater commercialization of AI could encourage the emergence of new products and services that meet the needs of modern tourists and streamline operations at tourism destinations.

We do not comment on the other clusters because their AU (Approximately Unbiased) p-value is below 0.9. This lower index suggests that the stability and reliability of the clustering is not high enough to rely on them for data interpretation and analysis. Lower AU values suggest that differences between clusters may be less consistent and clustering could be less accurate, reducing its value as a reliable tool for detailed analysis.

CONCLUSIONS

The impact of artificial intelligence and the emerging challenges in the tourism business are becoming more and more significant. The importance of this topic is indisputable, as the deployment of AI shapes the direction and further development of the tourism industry and determines its strategic management in the context of ensuring competitiveness, sustainability of business in this sector and equitable development. New technological innovations act as a catalyst for change and fundamentally affect the entire tourism sector in terms of efficiency, automation or personalisation. In the present paper, we applied principal component analysis and cluster analysis methodology. This combination yielded the discovery and exploration of interrelationships between selected variables such as the level of AI development and the share of tourism in GDP. We have demonstrated an uneven distribution of technologies, which raises the need for more targeted support for an even and sustainable development within the European Union countries. The development of AI depends primarily on the development of infrastructure, the availability of high-speed and broadband internet connectivity, qualified IT professionals, commercial integration into individual business processes and, last but not least, on the public policies in place to support investment in the expansion of AI. Our analysis revealed a lag in the development of AI technologies in the post-communist countries such as Slovakia, the Czech Republic, Romania, Latvia, Croatia, but also in the case of Greece. The findings can be a useful starting point for creating and shaping new development policies and investments in the application of artificial intelligence in tourism. Our analysis is based on data from 2019, due to the fact that it was the most recently observed year with relatively stable travel and economic conditions prior to the outbreak of the pandemic

disease COVID-19. The pandemic has fundamentally and broadly changed the conditions for tourism, which may not be included in the present research study. Based on the results, we have highlighted significant differences between EU Member States. However, it is important to note that not all countries provide data of the same quality, and in some cases, data availability is limited. Therefore, the data obtained will not capture all externalities, specificities or nuances resulting from locally specific legislative, economic or socio-cultural conditions. PCA is based on linear relationships between variables and thus may not capture all interaction relationships between tourism and AI. The analysis performed does not assess the long-term trends of AI development in tourism. The above could help to predict future directions and development phases. Based on our findings and identified challenges, we formulate the following possible research directions for the application of artificial intelligence in tourism: there will be a need for a deeper investigation of the differences in the use of AI across the European Union countries, with emphasis on regional infrastructural, economic or socio-cultural differences; there will be a need to identify and formulate specific public policies and investment strategies to address the regional disparities between less developed and developed EU countries; we recommend that longitudinal studies be carried out with the intention of assessing the development dynamics of AI over a longer time horizon; the impact of AI deployment and scaling-up on macro-economic (economic growth, employment, etc.) indicators will need to be investigated; the impact of AI deployment and scaling-up on macro-economic (economic growth, employment, etc.) indicators will need to be investigated.), on business-economic (customer preferences, customer satisfaction, etc.) and technological (synergistic relationships between AI and technology) indicators. For future research, we also identify opportunities for specifically focused research reflecting on the application of AI for individual forms of tourism such as mass tourism (e.g. automation of services for large volumes of tourists), luxury tourism (e.g. provision of personalized high quality services), ecotourism (e.g. finding optimization solutions for green sustainability and environmental protection).

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