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Research Article

Artificial Intelligence in Tourism Economics: Economic Growth, Overtourism, and Environmental Sustainability

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Abstract

Artificial Intelligence (AI) has become a part of the sales and operations of tourism. It is crucial for demand forecasting, recommendation engines, dynamic pricing, and service automation, and destination management. These tools can improve productivity and demand investment and can be used to help destinations manage their use of energy, water and space. They can also act in the opposite manner. Marketing and recommendation algorithms tend to attract more visitors to popular locations, exacerbating the congestion, transforming the infrastructure and polluting the environment, and efficiency can be offset by the greater travel resulting from the lower costs of travel. The paper reviews the literature regarding the adoption of artificial intelligence, the growth based on tourism, overtourism and environmental sustainability, based on endogenous growth theory, tourism area life cycle, environmental economics and the rebound effect. It then outlines a conceptual framework for these, eight research propositions and five panel-data specifications to be used in future studies to test these. The position here is that AI can only help build sustainable tourism if it is done with care. It relies on the design of the systems, on what they are optimized for and on the quality of the governance of destinations. Judging the adoption of AI should therefore be based on the impact it has on absolute environmental pressure, on residents and on who benefits economically, as well as on productivity and revenue.

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I. INTRODUCTION

Tourism generates employment, attracts investment, supports small and medium businesses (SMEs) and generates foreign exchange (Organisation for Economic Co-operation and Development [OECD], 2024). It promotes the development of the destination region by stimulating the demand for local products and services, and the tourism-led growth literature generally confirms this association, but its impact differs across countries and methods (Brida *et al*., 2016). Growth has costs. Increased tourism pressure on housing, infrastructure and ecosystems, and tourism contributes to 8% of global GHGs (Lenzen *et al*., 2018) when there are more people than a destination can cope with. It is the challenge for tourism economies to increase in a way that is economically viable, inclusive to local people and sustainable in terms of the environment. Digital technology has impacted the way tourism companies run and how tourists search for, purchase and travel through their experiences in tourism (Buhalis & Law, 2008). The next phase in that transformation is Artificial Intelligence (AI). In tourism, it manifests in the form of chatbots, personalized recommendations, demand forecasting, facial recognition, service robots, dynamic pricing, sentiment analysis and smart destination management. They handle significantly more information and process it much quicker than traditional approaches and have been adopted across various marketing, visitor experience, operations and destination governance applications (Tuo *et al*., 2025).

The economic argument is simple. AI reduces expenses, improves service, assists in pricing and enables companies

to identify demand fluctuations. A hotel can prepare their hotel rooms and allocate staff based on its predictive analytics; a booking site can match travelers with a hotel and the hotel services they are looking for. Technological innovation is acknowledged as a driver of productivity growth and long-run development (Romer, 1990), and a study of 10 leading tourist destinations from 2010 to 2022 shows a positive relationship between the adoption of AI and tourism growth (Siddik *et al*., 2025). It has other, less desirable attributes. Faster, cheaper and more personal travel increases travel. Recommendation algorithms gravitate towards places that already have attention on the internet, so that they can help focus attention on a more even distribution. This is most important in places already affected by crowding, house shortages, congestion and waste. In this context, overtourism can be considered an issue of sustainability, where the number of visitors is not the deciding factor and the sustainability of a place is not just about its ability to sustain tourism but also its ability to sustain tourism without jeopardizing the quality of life of its residents and its long-term attractiveness (Koens *et al*., 2018).

The environmental picture is a mixed one, similarly. AI can also control the heating, cooling and lighting systems in hotels based on occupancy, control transport systems, manage water systems, monitor waste and predict environmental pressure, and there are many studies pointing to its potential contributions to sustainable tourism and Sustainable Development Goals (SDGs) (Alves *et al*., 2025; Gössling & Mei, 2025). However, efficiency is not necessarily equal to less impact. In addition to cutting down on the expense and hassle of travel, this additional demand could take up some or all of the savings. This is called the rebound effect (Sorrell, 2009). If a hotel has a lower per room energy usage, but also a lower occupancy, then it can have a higher overall energy usage.

AI can then assist in the growth of tourism and contribute to the factors driving overtourism and environmental harm. The impact will be from whichever side is more prominent – depending on the design, adoption and regulation of the technology. The body of research on the topic has grown rapidly and is a bit diffuse. Studies may focus on specific applications, on consumers' acceptance or on just one sustainability practice, and rarely combine these in a tourism economics framework. Recent reviews also agree and recommend the need to provide more robust empirical evidence and integrated approaches (Alves *et al*., 2025; Belkaid & Kummitha, 2026).

This paper is a critical narrative review that has four aims. The first is to explain how economic mechanisms could impact the productivity and competitiveness of the tourism sector as well as investments and job creation as a result of the use of AI. The second is to examine the impact of AI-powered marketing and recommendation platforms on augmenting and/or reallocating tourist demand. The third is to evaluate how AI can help environmental management considering its own energy consumption and rebound effects. The fourth is to bring these strands together in a conceptual structure, specifying propositions to be tested, and providing model specifications for future empirical work. The contribution is to frame the relationship between AI and sustainable tourism on a conditional basis: An AI that enables sustainable tourism can be beneficial when it contributes to the enhancement of productivity and the coordination of the tourism, while also resulting in effective visitor management, environmental control, and transparent governance and protection of local communities. In section II the theory is given. Sections 3-6 are an overview of growth, overtourism, environment and governance. Research gaps, the framework and propositions, the empirical models and policy implications are discussed in Sections VII to X. Limitations and conclusions are made in sections XI and XII.

II. THEORETICAL FOUNDATIONS

A. Artificial Intelligence in Tourism

AI is an umbrella term for technologies that let computer systems do things that normally require human cognition: learning from data, recognizing patterns, understanding and generating language, making predictions and supporting decisions. There are four families of applications that are most important in the field of tourism. Machine learning identifies patterns out of historical and real-time data, and can forecast room demand, cancellations, pricing, congestion and environmental stress. Chatbots and virtual assistants are powered by NLP, while generative AI takes it further with personalized itineraries and conversational recommendations. Recommendation systems are based on preference, search history, reviews, and location to recommend products or destinations. They can simplify planning but can also create a concentration of demand when algorithms continue to favor the already popular or digitally visible locations. Robotics and automation are evident in automated check-in and cleaning robots, and luggage handling, with their economic impact related to implementation and maintenance costs, customer acceptance and suitability of the task for automation.

Smart tourism is the broader context. It is the process of incorporating digital technologies, data infrastructure, tourism services and destination-management systems in such a way that the visitor, business and local authority are linked to one another through shared information (Gretzel *et al*., 2015). AI is the layer of analysis and decision-making of that environment.

B. Endogenous Growth and Technological Innovation

Neoclassical growth theory (in the form of the Solow (1956) model) accounts for growth by increases in capital, labour and technological progress but assumes that technology comes from outside the economy. Endogenous growth theory makes technological progress the result of economic

decisions. Romer (1990) demonstrates that technological change is possible as a result of deliberate investment in knowledge, which can be adopted by multiple firms simultaneously leading to spillovers. Aghion and Howitt (1992) also argue that innovation can also replace existing products and companies.

AI can contribute to the growth of tourism in four ways within this framework. Companies invest in it to boost productivity, digital innovation creates new products and services, AI-related investments increase needs for skilled workers, and information AI systems provide help with decision-making in businesses and public institutions. These benefits are not achieved by the technology alone. Digital infrastructure, skilled workforce, funding and organizational capacity to integrate AI into processes and destinations with data-sharing, cybersecurity and institutions capable of translating digital data into policy are all essential prerequisites. The research on general-purpose technologies reveals that complementary investing in such technologies is expensive and slow to return a measure of productivity (Brynjolfsson *et al*., 2021). The theory thus suggests that there will be a positive but non-linear link between the adoption of AI and the growth of tourism, with the greatest benefits in economies with robust institutions, talented workforce, and advanced infrastructure.

C. The Tourism Area Life Cycle

The tourism area life cycle model developed by Butler (1980) suggests that destinations go through stages of exploration, involvement, development, consolidation and stagnation, and then decline or rejuvenate. With rapid growth comes its restrictions which are set by the infrastructure, environmental resources and local acceptance. AI impacts both the rate and the spread of this advancement. A series of marketing tactics can make a destination more popular, and even cause a place that was not very well known to see rapid growth after being promoted on social media and other channels, and then recommended by others. AI can also be used for rejuvenation purposes by offering alternative attractions, share visitors and handle the load of seasonal demand. The life-cycle view separates two things that are easily run together: increasing demand and managing development. Mature destinations might want to attract visitors of a certain quality, to lessen the demand on the environment, to extend the tourist season and the sharing of the benefits of tourism, and more visitors is not always better.

D. Externalities and Carrying Capacity

Tourism has external effects in both directions. The good news is employment, infrastructure investment, preservation of cultural heritage and conservation funding. On the downside are the carbon emissions, water usage, solid waste, noise, congestion, and disturbance and pressure of habitat and local housing. Pigou (1920) said that negative externalities are the result of the fact that the private decision makers do not have to pay the full social cost. In reality, when a visitor visits the price paid is often less than this cost, so that market demand may exceed the socially desirable demand. AI can help to close the gap by enhancing measurement, monitoring and allocation and the data it generates can be used to feed into congestion charge schemes, reservation systems and differentiated pricing. Technology can't replace regulation. Visitor counts can be excessive as part of a monitoring process and the monitoring system can report this; however, that monitoring system cannot be used to stop visitors entering an authority's premises.

Carrying capacity provides more substance to the notion of a limit. It is not a fixed number and is the degree of tourism that a destination can receive without unacceptable environmental degradation (McCool & Lime, 2001). This is dependent on ecological sensitivity, infrastructure, the behaviour of visitors, season, the quality of management and what local communities are willing to accept. A coastal area can be limited on water availability/waste treatment and a historic city on public transport/housing and public space and a mountain area on erosion/biodiversity loss. AI can help with this by integrating data from sensors, satellite imagery, mobile devices, ticketing systems and transport platforms to enable authorities to issue timed entry tickets, temporary access bans or dispersal measures. This monitoring comes with concerns of privacy, data ownership, accuracy and fairness, and unassisted algorithms setting carrying capacity. There is a need for scientific assessment and local knowledge.

E. The Rebound Effect

The rebound effect is the situation in which a policy or measure that results in higher resource efficiency, and therefore a lower cost of an activity, also increases the amount of the activity. In some instances, the additional consumption completely negates the projected savings (Sorrell, 2009). There are two obvious paths for tourism. If the BMS can reduce energy consumption per cubic metre of occupied space, but the lower operating costs allow the hotel to grow or fill up more, then the total energy consumption could increase.

AI-driven planning can eliminate a lot of the planning workload, meaning that they can save a lot of time and effort when arranging a trip; it can create even more travel when it also sends some people off on recommendations for other destinations. The reduction in energy consumption per visitor is therefore not a reflection of overall energy consumption, and absolute measures are needed, as well as measures of efficiency. The theoretical lenses and the implications for AI in tourism are presented in Table I.

TABLE I THEORETICAL LENSES USED IN THIS REVIEW

Lens	Core idea	Implication for AI in tourism
Endogenous growth theory (Romer, 1990)	Technological change results from investment in knowledge and generates spillovers.	AI raises productivity and growth where skills, infrastructure and institutions are in place.
Tourism area life cycle (Butler, 1980)	Destinations grow until they meet limits of infrastructure, environment and local acceptance.	AI can speed up growth through digital visibility, or support rejuvenation through dispersal and seasonal management.
Externalities (Pigou, 1920)	Prices do not reflect the full social cost of tourism.	AI improves the measurement and pricing of externalities but cannot replace regulation.
Carrying capacity (McCool & Lime, 2001)	The limit varies with ecology, infrastructure, visitor behaviour, season and management.	AI helps forecast and manage visitor pressure; setting limits still needs scientific assessment and local knowledge.
Rebound effect (Sorrell, 2009)	Efficiency gains lower costs and stimulate consumption.	Savings per visitor can be offset by more visitors, so absolute indicators are needed.

III. AI AND ECONOMIC GROWTH IN TOURISM

Sections III to V examine what AI does for tourism growth, tourist demand and the environment. Table II gives an overview of the main applications, with the economic benefit, the environmental opportunity and the principal risk of each.

TABLE II AI APPLICATIONS IN TOURISM: ECONOMIC BENEFITS, ENVIRONMENTAL OPPORTUNITIES AND RISKS

AI application	Economic benefit	Environmental opportunity	Potential risk
Predictive analytics	Better demand forecasting, staffing and capacity planning.	Better allocation of energy, water and transport capacity.	Forecast-driven expansion may increase total visitor volumes.
Recommendation systems	More relevant offers; higher conversion and visitor spending.	Can direct visitors to less crowded locations and off-peak periods.	May reinforce popular attractions and concentrate demand.
Dynamic pricing	Better revenue management and demand balancing.	Higher peak prices may moderate pressure if alternatives are promoted.	Can shift demand unevenly or reduce access for some visitors.
Smart energy systems	Lower operating costs; more efficient facility management.	Optimized heating, cooling, lighting and energy use.	Savings may be offset by larger facilities or higher occupancy.
Intelligent transport	Fewer delays; better transport coordination.	Route optimization; better integration with public transport.	Convenience may encourage more trips and increase total mobility.
Service robots	Labour support, consistent service and operational efficiency.	Potentially more precise resource use in service operations.	Energy use, electronic waste and job displacement.

A. Productivity and Operations

Increased productivity is the most apparent economic impact of AI. AI systems can extract data from all these areas, helping to make informed decisions about tourism operations that need to be made all in one go: dealing with fluctuations in demand, staffing schedules, and inventory, as well as managing transport and service quality according to the season. In hotels, more accurate forecasts reduce the labour costs during quieter times and avoid the shortage during peak times.

AI is being applied in airlines and transport companies for route planning, scheduling, capacity planning, and predictive maintenance to flag equipment faults before it disrupts. Only when restaurants' food waste forecasts influence the way in which they buy and produce food can this approach prevent food waste. The benefits are related to implementation. A bad system yields false predictions, increased maintenance expenses or additional administrative workload, and small businesses must also struggle to fund AI systems and to recruit employees with the technical expertise needed for their implementation.

B. Competitiveness, Innovation and Investment

AI enables companies to answer their clients' needs. Customized recommendations, real-time data and easy communication increase customer satisfaction, while automation reduces waiting times and extends service hours. Platforms can offer firms packages that incorporate a stay and travel, plus entertainment and cultural activities; this allows them to differentiate themselves in competitive markets and destination authorities can use platform data to understand what visitors like, spend and look for in the different seasons to guide their marketing. Adoption also entails investment in cloud computing, cybersecurity, customer-management platforms, intelligent building systems and new business models, including digital travel platforms, intelligent accommodation services and data-driven destination-management companies.

Two cautions apply. The first is that competitiveness is not equal to the number of visitors attracted. A destination can gain visitors and have them be satisfied with their visit and experience, although the area may be experiencing congestion, environmental degradation, and the residents are becoming disenchanted with the area, and its long-term competitiveness relies on the natural, cultural and social

resources that initially attracted visitors. The second is that the returns of the AI investment are unevenly distributed. But when AI is made available as a requirement to be seen or have customers, small local businesses may find themselves at the mercy of the large hotel platforms.

C. Employment

The impact of AI on tourism is multifaceted, with the potential to affect jobs in both positive and negative ways. Some repetitive activities, such as routine customer enquiries, routine administration, and some types of service operations, are not required, as they can be automated. This also generates a demand for data management, software coding, digital marketing, cyber security and technology maintenance. It depends on the net change in the tasks that are displaced by AI and others that are introduced and better products (Acemoglu & Restrepo, 2019). Given the nature of the service industry of tourism where the valued attribute of the visitor is hospitality, cultural interpretation and personal attention, full automation is not suitable for many services, and the realistic prospect is the use of AI to assist staff. There will still be differences in the adjustment costs. There is a high level of insecurity for workers with limited digital skills and new opportunities for highly-skilled workers; that's why training is part of any responsible adoption plan.

D. Nonlinear Returns to Adoption

The economic impact of AI will probably not be linear. Early adopters are likely to invest in a large up-front expense, train employees to use the software, and deal with integration issues and ROI challenges that can dampen short-term earnings. The more experience firms have, the greater the productivity benefits. This is similar to the productivity J-curve observed with general purpose technologies (Brynjolfsson *et al*., 2021). There are some costs and risks associated with the adoption at high levels: the platform dependence, the costs of managing data and the technological complexity, as well as the cybersecurity risk, all of which will be borne by the firms. It is therefore possible that there is an inverted-U relationship (Figure 1a). It is possible, but not necessarily proven in practice yet and the shape of which will depend on the quality of institutions, digital infrastructure, human capital, size and management skill of the firm.

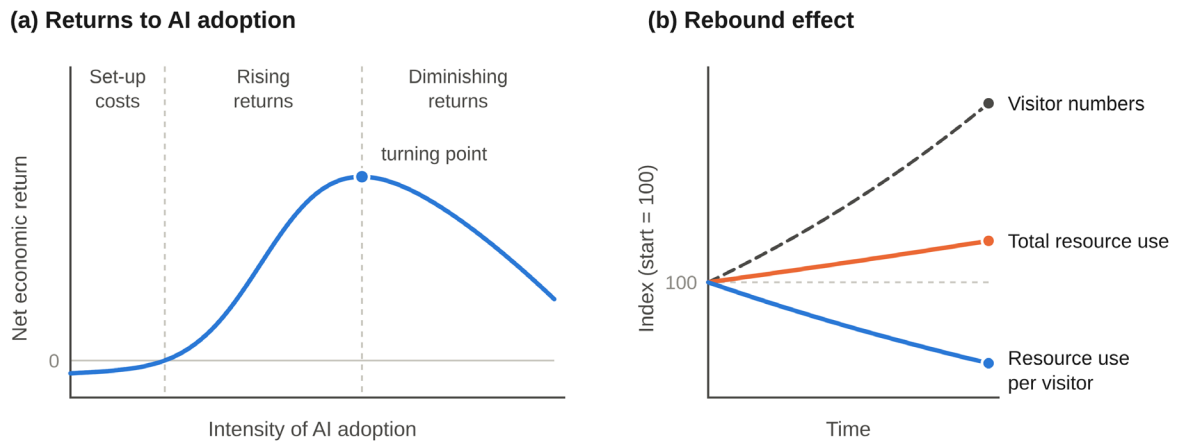

Fig.1 Stylized illustrations of two nonlinearities discussed in the text. (a) A possible inverted-U relationship between the intensity of AI adoption and net economic return. (b) The rebound effect: resource use per visitor falls while visitor numbers grow, so total resource use rises. Both panels are schematic and are not drawn from data.

IV. AI, TOURISM DEMAND AND OVERTOURISM

A. Algorithmic Visibility and the Concentration of Demand

With AI, companies and platforms can process user data in a scalable way. Recommendation systems: they deduce travel preferences, forecast purchases and advertise; accordingly, generative systems: they draft travel plans for specific travelers. The search process speeds up and the results they select are influenced by the system they are presented with. Reducing information barriers raises demand, and it can be raised in two ways. Can add another layer of visitors to places that are already crowded, or it can introduce people to places that may have been overlooked. The second outcome is the consequence of the way the algorithms learn as shown in Figure 2. The more reviews, photos, searches and interactions there are, the more popular it is. The more important the signals, the higher it is ranked, and the more people will come, the more signals will be made. The same is true of recommender systems in retail: recommenders based on past transactions can decrease the variety of products sold (Fleder & Hosanagar, 2009). Where the infrastructure is there, and the interest is there, less visible destinations are then hard-pressed to compete.

Overtourism occurs when the pressure becomes unacceptable for the destination, its people, infrastructure and/or environment. It's not limited to numbers of visitors. The impact is dependent on the destination area in which visitors stay, their timing of arrival and length of stay, and how well they are managed there (Koens *et al*., 2018). The economics don't make any sense. With high numbers of

visitors come higher sales, employment and business revenues, and higher rents, congestion, and demand for public services, until residents start opposing the tourism. Overtourism is thus more a distribution, management and carrying capacity issue than a total demand one, and should be investigated in this regard.

B. AI as a Cause and as a Remedy

Four AI-related mechanisms feed the loop in Figure 2. Personalized recommendations reduce the cost of search and encourage additional travel. Popularity-based algorithms focus popularity on destinations with a high level of engagement on the Internet. Dynamic pricing and advertising boost demand during the most profitable times, and automated planning makes frequent trips easier to organize. All this does not mean that overtourism is a direct outcome of AI. It's about the commercial incentives and algorithmic design guiding tourist flows and their timing. There is no rationale for a recommender who is only interested in clicks, bookings or revenue to be concerned with the capacity of the environment or local welfare.

The same technology enables authorities to control the number of visitors. Predictive analytics can help predict congestion, timed entry allows for a spread throughout the day, and platforms can guide visitors to quieter periods and alternate attractions, or to other seasons. The extension of the season requires management as sensitive environments have a range of ecological limits throughout the season. Dynamic pricing can also discourage visits during periods of high demand, but at that time access will depend on income, so pricing schemes need to be developed in conjunction with public-access policies and safeguards for local communities. The tests of these tools are the residents. Digital indicators will identify the congestion and pressure on public services, but they will not reflect how it feels to the public and so consultation and local knowledge will be needed. AI-DM should be evaluated for its ability to generate tourism revenue to sustain local employment, to boost small businesses and public infrastructure, to increase residents' cost of living, and to crowd out residents from public space or displacement.

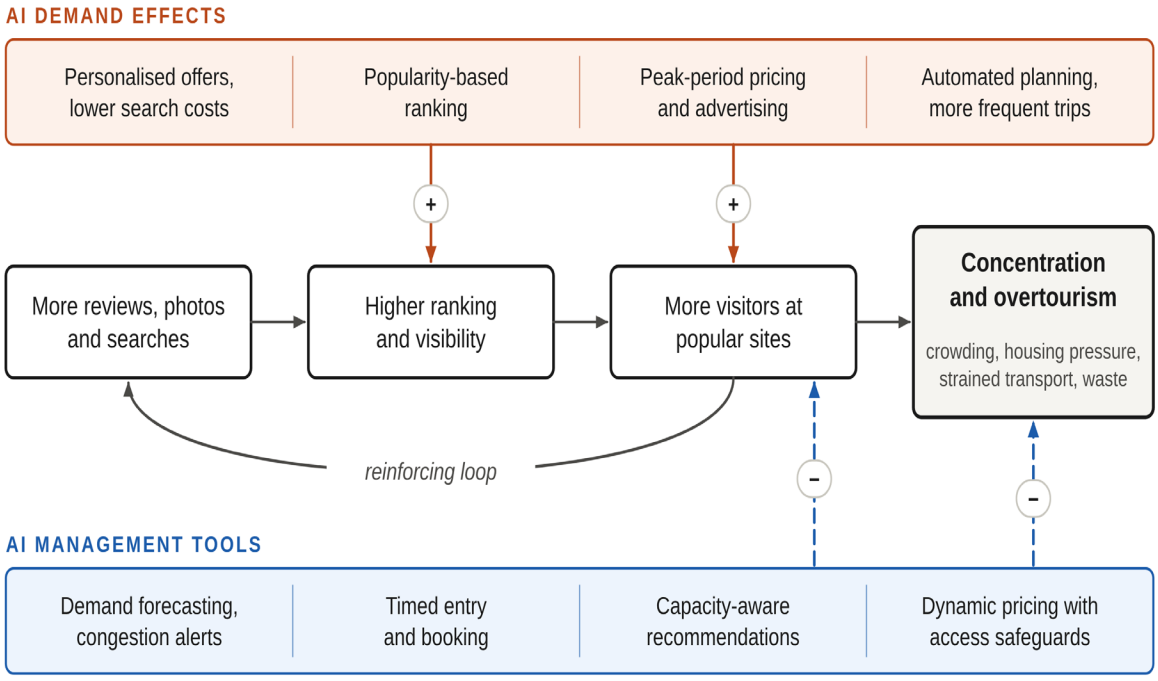

Fig.2 How AI can intensify or relieve overtourism. Demand effects feed a reinforcing loop in which popular sites attract more online activity, rank higher and draw more visitors. Management tools act on visitor numbers and on concentration. Solid arrows indicate an increase and dashed arrows a reduction.

V. AI AND ENVIRONMENTAL SUSTAINABILITY

A. Resource Management Applications

Hotels, resorts, airports and transport systems use large amounts of energy and water and generate waste and emissions, and AI is applied to each (Table III). Predictive control adjusts heating, cooling and lighting to occupancy and weather. Consumption analytics detect leaks and abnormal water use. Demand forecasts and image recognition measure and reduce food waste, which matters because discarded food embodies agricultural inputs, energy, water, labour and transport. Route optimization and passenger-flow data make transport more efficient, and satellite imagery and computer vision help conservation authorities detect changes in vegetation, wildlife movement and land use.

TABLE III ENVIRONMENTAL APPLICATIONS OF AI IN TOURISM AND THE CONDITIONS FOR A REAL BENEFIT

Domain	What AI does	What the benefit depends on
Energy	Predictive control of heating, ventilation, air conditioning and lighting from occupancy and weather data; predictive maintenance of inefficient equipment.	Cleaner energy sources: savings not absorbed by larger facilities or higher occupancy.
Water	Analysis of consumption patterns, detection of leaks and abnormal use, demand prediction, smart irrigation.	Water-saving infrastructure, maintenance, appropriate pricing and destination-level water plans.
Waste	Food-demand forecasting, image recognition of discarded food, automated sorting and recycling, analytics for waste collection.	Changes in purchasing and production; investment in collection and recycling.
Transport	Route optimization, traffic prediction, scheduling, predictive maintenance, integrated mobility systems.	Availability of lower-emission options; policies that favor public transport, active mobility and cleaner vehicles.
Biodiversity	Satellite imagery and computer vision to detect changes in vegetation, wildlife movement and land use; digital booking and visitor monitoring in protected areas.	Ecological expertise, field assessment and local participation; allowance for prediction errors.

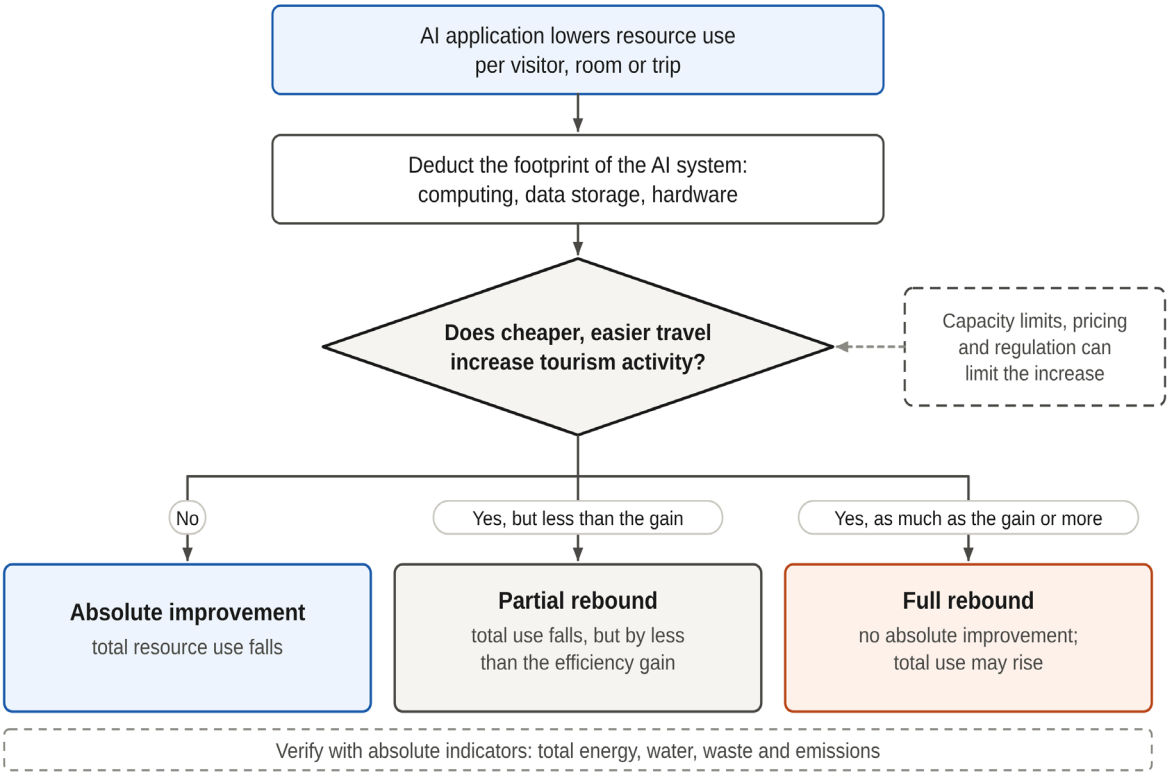

Fig.3 From an efficiency gain to a net environmental outcome. The saving per visitor is first reduced by the footprint of the AI system and then by any increase in tourism activity that cheaper or easier travel brings about. Only total resource use shows which of the three outcomes has occurred.

Two points apply across these uses. The first is scale. Tourism's share of global water use is small, but hotels, golf courses, pools and landscaping can put heavy pressure on local supplies where freshwater is limited (Gössling *et al*., 2012), so the test in water-stressed places is whether tourism leaves enough for residents, agriculture and ecosystems. The second is that information does not act unaided. A restaurant can receive accurate waste forecasts and leave its purchasing unchanged. A destination can monitor waste without investing in collection and recycling, and travellers can be shown a lower-emission option that the infrastructure does not provide. Conservation decisions still require ecological expertise, field assessment and local participation, because AI systems make errors.

B. Net Effects: the Footprint of AI and the Rebound Effect

AI comes with an environmental price. It requires computing infrastructure, data storage, networks, electricity, and a single LLM can use a significant amount of energy (Strubell *et al*., 2019). Tourism businesses can use a variety of digital systems without considering the combined needs of these systems, and cloud computing, automated services and constant data collection increase in electricity consumption and electronic waste. This footprint can be reduced with energy-efficient computing, renewable electricity and responsible hardware management – but it needs to be counted. Rebound (Section II) is the bigger problem. The effect of each tourist/service is reduced by

efficiency gains and can be offset by increased tourism activity (Figure 1b). Reducing emissions per passenger does not necessarily involve a decrease in absolute emissions, but rather an increase in the number of passengers when emissions are reduced. The efficiency gain to its net effect is illustrated in Figure 3. Relative indicators calculate the use of resources per visitor, per room or per gross income and absolute indicators calculate the total energy consumption, emissions, water use/waste. There is a need for sustainable tourism to go in the right direction, and both of them must do that. If one part of a business has gotten better, it's not a sustainable change. The claim should be backed by evidence of declining overall impact.

This applies to the SDGs as well. AI can help with decent work and growth (SDG 8), innovation and infrastructure (SDG 9), sustainable cities (SDG 11), responsible consumption and production (SDG 12) and climate action (SDG 13), as well as the goals for life below water and on land, through environmental monitoring. In both, the contribution is contingent on something technology can't provide – namely, addressing labour displacement and the lack of access to skills, not limiting the benefits to large firms or rich destinations, prioritizing residents' welfare in destination policy, and ensuring that climate actions lower absolute emissions. A recent review also comes to the same conclusion (Alves *et al*., 2025; Gössling & Mei, 2025).

VI. GOVERNANCE AND RESPONSIBLE ADOPTION

Governments and destination-management organizations influence the conditions in which AI is being adopted – digital infrastructure, environmental regulation, data protection, competition and tourism planning. AI is also being employed by them to enhance public services, predict visitor numbers and track environmental strains. The main governance issues, the risk associated with each and the response required are detailed in Table IV.

TABLE IV GOVERNANCE ISSUES IN AI-ENABLED TOURISM: RISKS AND RESPONSES

Issue	Risk	Response
Public data capacity	Authorities depend on commercial platforms whose data are incomplete, commercially biased or unavailable to public bodies.	Transparent data partnerships; standards for data collection and sharing; capacity to evaluate digital information independently.
Privacy and security	Unclear consent, excessive data collection, unauthorized access and weak cybersecurity undermine consumer trust.	Collect only the data needed; secure systems; publish clear privacy policies.
Algorithmic bias	Recommenders favor destinations, businesses and consumer groups already well represented online.	Audits to detect discriminatory patterns and unintended effects.
Transparency	Businesses, consumers and authorities cannot see how recommendations and automated decisions are produced.	Explain how systems collect data and generate recommendations.
Institutional quality	Adoption driven by short-term commercial incentives; environmental information left out of decisions; gains concentrated in a few firms.	Clear rules, enforced environmental standards, accountability and public participation.
Digital inequality	High costs and limited skills hold back small businesses; market concentration increases.	Affordable digital infrastructure, training programmes, shared technology services and technical advice.

There are three points that should be addressed. It is important for public authorities to not rely solely on commercial platforms to provide them with information on their own destinations, as such information can be partial, biased and not obtainable by public authorities. Bias in recommender systems is not a technical but also a distributional question. Regional small suppliers struggle to be visible when platforms consistently prioritise large suppliers, and the digital divide between large and small firms grows. If the institutions are good, all else is good. In weak governance environments, adoption is largely based upon short-term, commercial motives, environmental information is largely excluded from decision making, and benefits are targeted to a limited number of firms. Hence, institutional capacity may be considered as a moderator between AI adoption and sustainability outcomes. The same technology will yield varying outcomes depending on the degree of regulatory quality, accountability, public participation, enforcement and the number of technologies adopted, and as long as these outcomes benefit not only large technology companies and international platforms, but local businesses, workers, and communities, too, it can be considered responsible.

VII. DISCUSSION AND RESEARCH GAPS

A. The Economic and Environmental Trade-off

A key question revolves around the trade-off between enhancing economic performance and boosting environmental pressure, which is a central theme in this literature. Tourism growth brings an additional level of transportation, increased energy consumption, waste production and natural resources pressure, while providing productivity benefits, reduced transaction costs and targeted marketing. A tourist destination can boost revenue from tourism but end up worsening the very environment upon which tourism relies. The two pathways are outlined in Figure 4. The benefits of technological efficiency accrue per tourist, while the pressures of tourism increase with the number of tourists. Economic growth is important but it's not enough to be sustainable development.

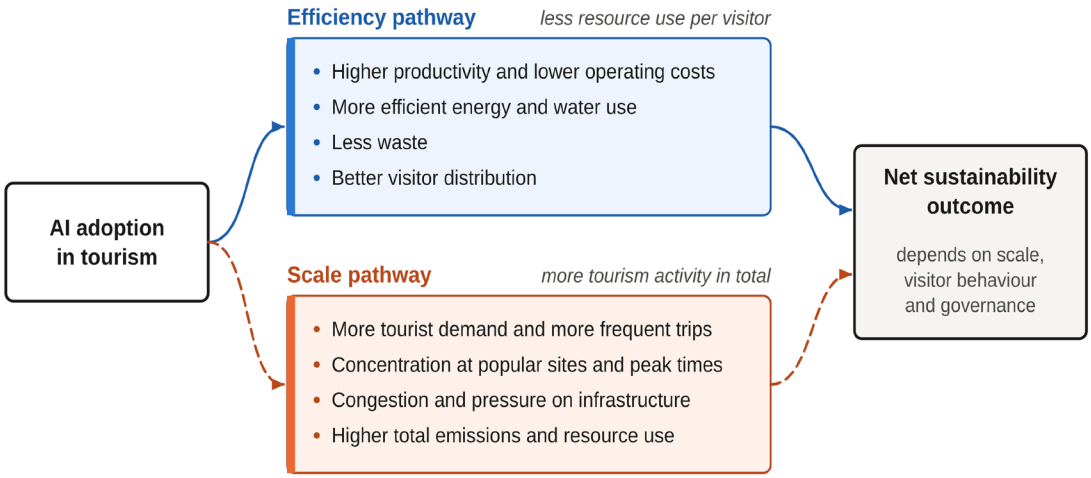

Fig.4 Two pathways from AI adoption to Tourism Sustainability. Efficiency Gains Lower Resource Use Per Visitor, While Demand Effects Raise the Scale of Tourism Activity. The Net Outcome Depends on Which Pathway Dominates.

A second issue is integration. Most studies focus on the use of single applications, and an application that is good for one stakeholder is bad for another. Dynamic pricing increases hotel revenue and may allow for less affordable hotel accommodations for certain visitors and/or residents. Automated services reduce business expenses and generate adjustment pressure to the workforce. Personalized marketing raises a destination's visibility and heightens congestion.

B. Gaps in the Evidence

There are six gaps that are listed in Table V, with two of them requiring explanation. The first one is measurement. There are many studies that report on perceptions of, intentions or expected benefits of AI which are useful in the understanding of attitudes; however, these studies do not show reductions in energy use, water use, waste or emissions. The relative efficiency could be measured against the absolute performance if the operational data (energy use at the hotel, food-waste measurements, transport emissions, numbers of visitors at a destination, etc.) were known.

The latter is functional form. The relationship between AI and sustainability is not necessarily linear, as in Section III, and it is also asymmetric: as the efficiency of firms slows down, they may still reap benefits from AI, but the environmental costs of increased demand for tourism may still be felt. Once the carrying capacity of a tourism destination is reached, the growth rate of tourism can impact the environment more significantly. With more than a certain number of visitors below that point, the damage is negligible. After that, traffic jams and ecological strain grow rapidly. These patterns will be absent from linear models.

The other gaps have to do with coverage. There is a lack of systematic studies on differences between destinations, little research addressing distributional effects on SMEs, workers and residents, and much of the research has relied on cross sectional surveys that capture associations but not causal impacts over time. The analysis at the destination level is required in conjunction with the firm level analysis, as a hotel may increase its energy efficiency, but increase the overall energy use at the destination.

TABLE V RESEARCH GAPS AND THE EVIDENCE NEEDED TO ADDRESS THEM

Gap	Limitation of current work	What future studies should do
Absolute environmental impacts	Reliance on perceptions, intentions and expected benefits.	Use operational records of energy, water, food waste and emissions; report absolute and intensity-based measures.
Nonlinear and asymmetric effects	Linear specifications.	Test for nonlinearity, asymmetry and carrying-capacity thresholds.
Institutional and digital capacity	Little comparison between destinations with different infrastructure and governance.	Treat institutional quality, digital infrastructure, human capital and regulatory capacity as moderators.
Local communities and distribution	Limited attention to who gains and who bears the costs.	Examine employment quality, SME participation, resident satisfaction, housing affordability and access to public services.
Longitudinal and destination-level evidence	Cross-sectional surveys, mostly at firm level.	Use longitudinal designs, destination-level and regional data, and mixed methods.
Differences between technologies	AI treated as a single category.	Distinguish machine learning, generative AI, robotics and predictive analytics, and their operational uses.

VIII. CONCEPTUAL FRAMEWORK AND RESEARCH PROPOSITIONS

TABLE VI RESEARCH PROPOSITIONS, EXPECTED DIRECTION OF EFFECT AND CORRESPONDING MODEL IN SECTION IX.

Propositions	Relationship	Proposition	Expected effect	Model
P1	AI adoption and tourism economic growth	AI adoption improves tourism economic performance by raising productivity, operational efficiency, innovation and competitiveness. The strength of the effect depends on infrastructure, human capital and organizational capability.	Positive	1
P2	Nonlinear returns	The relationship between AI adoption and economic performance may be nonlinear because of initial implementation costs, learning effects and diminishing marginal returns.	Possibly inverted U	2
P3	AI-driven marketing and overtourism	AI-powered recommendation and marketing systems may increase tourist demand and destination concentration when algorithms prioritise historically popular locations and commercial engagement.	More concentration	Not covered
P4	AI-enabled destination management	AI-supported forecasting and visitor management may reduce overtourism by improving the distribution of visitors across locations and seasons, particularly when environmental capacity is built into decisions.	Less concentration	Not covered
P5	AI adoption and environmental efficiency	AI adoption may improve environmental efficiency through better energy management, water conservation, waste reduction and transport optimization.	Positive	3
P6	Tourism growth and environmental pressure	Tourism economic growth may increase environmental pressure when visitor demand expands beyond the capacity of infrastructure and ecosystems.	More pressure	3, 5
P7	Institutional quality as moderator	Institutional quality may strengthen the positive relationship between AI adoption and environmental sustainability by improving regulation, transparency, accountability and implementation.	Positive moderation	4
P8	Rebound effects	Efficiency improvements generated by AI may be partly or fully offset by increased tourism demand, which weakens the link between AI adoption and absolute environmental improvement.	Offsetting	5

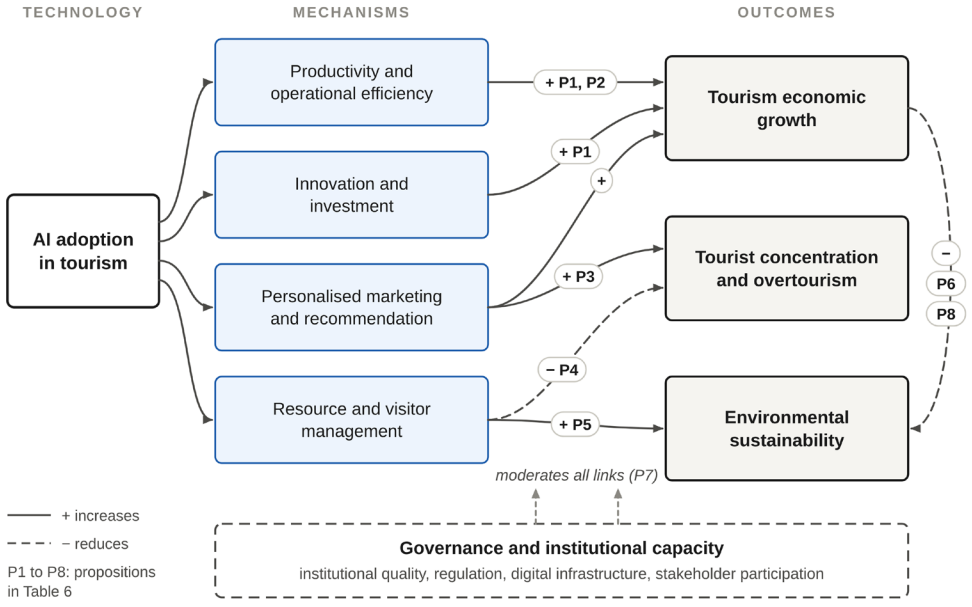

Fig.5 Conceptual Framework Linking AI Adoption to Tourism Economic Growth, Overtourism and Environmental Sustainability. Solid Arrows Indicate a Positive Expected Effect and Dashed Arrows a Negative One. P1 to P8 refer to the Propositions in Table VI.

Figure 5 summarizes the argument. AI has three impacts on the tourism outcomes, and governance conditions all three. There are two mechanisms in the economic pathway leading from productivity, operational efficiency, innovation and investment to tourism revenue, value added and employment. Marketing and recommendations are the demand pathway, reduce the information barriers and provide stimulus to travel and, depending on their design, broadcast travel spreads across locations and seasons or lead to concentrated travel in popular locations. The

environmental-management pathway encompasses energy efficiency, water management, waste reduction, transport planning and visitor monitoring, and all of these are a reduction in environmental pressure provided the efficiency gains translate to a reduction in the use of resources. The benefits of AI transform into sustainable results thanks to institutional quality, regulatory capacity, digital infrastructure, and data protection and participation. Eight propositions follow from the framework (Table VI). They are worded cautiously because each describes a relationship that the literature suggests and has not yet established.

IX. PROPOSED EMPIRICAL MODELS AND VARIABLE MEASUREMENT

This paper is a conceptual review, but the framework is meant to be tested. In empirical terms, AI adoption is the explanatory variable, tourism growth and visitor concentration are outcomes, environmental sustainability is a multidimensional outcome and governance is a moderator. The five specifications below are proposals for future panel studies, and none has been estimated here. Throughout, i indexes destinations or countries and t indexes time, μi and λt are destination and time effects, and εit is the error term.

The baseline model tests whether AI adoption is associated with tourism economic performance:

$$TEG_{it} = \alpha + \beta_1 AI_{it} + \beta_2 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

where TEGit is tourism economic growth, AIit is AI adoption or AI-related technological development, and Xit is a set of controls such as GDP per capita, foreign direct investment, inflation, trade openness, human capital, urbanisation and digital infrastructure, several of which appear in existing work on AI and tourism growth (Siddik *et al*., 2025). A squared term allows the relationship to bend:

$$TEG_{it} = \alpha + \beta_1 AI_{it} + \beta_2 AI_{it}^2 + \beta_3 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

A positive β1 with a negative β2 is consistent with an inverted U, and a positive β2 points to a U shape. Coefficient signs are not enough to establish either. The turning point has to fall inside the observed range of AI adoption, and the slope should be tested at both ends of that range (Lind & Mehlum, 2010). Environmental performance can be examined with:

$$ES_{it} = \alpha + \beta_1 AI_{it} + \beta_2 TG_{it} + \beta_3 Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

where ESit is environmental sustainability, TGit is tourism growth and Zit collects other controls. Absolute and intensity-based measures of environmental sustainability should both be used where the data allow, since they can move in opposite directions. An interaction term captures the moderating role of institutions:

$$ES_{it} = \alpha + \beta_1 AI_{it} + \beta_2 IQ_{it} + \beta_3 (AI_{it} \times IQ_{it}) + \beta_4 Z_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

where IQit is institutional quality, for which the Worldwide Governance Indicators are a common source (Kaufmann *et al*., 2011). A positive and statistically significant β3 would suggest that stronger institutions strengthen the relationship between AI adoption and environmental sustainability. A final model asks whether tourism growth changes the environmental effect of AI:

$$EP_{it} = \alpha + \beta_1 AI_{it} + \beta_2 TG_{it} + \beta_3 (AI_{it} \times TG_{it}) + \beta_4 W_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (5)$$

where EPit is environmental pressure and Wit is a set of additional controls.

TABLE VII VARIABLES, POSSIBLE MEASURES AND EXPECTED RELATIONSHIPS

Variable	Possible measurement	Expected relationship
AI adoption	AI-related investment, AI patent activity, AI readiness, digital adoption indicators or AI-related business use	Positive for productivity; environmental effect may be conditional
Tourism economic growth	Tourism value added, tourism contribution to GDP, tourism receipts or tourism employment	Dependent variable in growth models
Tourism demand	International arrivals, domestic visitor numbers, overnight stays or tourism expenditure	May increase with AI-enabled marketing
Overtourism	Visitor density, visitor-to-resident ratio, seasonal concentration, congestion or pressure on attractions	May increase if demand is concentrated
Environmental sustainability	Tourism-related emissions, energy intensity, water intensity, waste generation or environmental performance	Expected to improve under effective management
Institutional quality	Regulatory quality, government effectiveness, rule of law or accountability indicators	Expected to strengthen sustainable outcomes
Human capital	Education, skills, training or labour productivity indicators	Expected to support effective AI adoption
Digital infrastructure	Internet access, broadband availability, digital connectivity or technology readiness	Expected to strengthen AI benefits
Foreign direct investment	FDI inflows or tourism-related investment	May support economic growth and infrastructure
Inflation	Consumer price index or inflation rate	May affect tourism costs and demand
Urbanisation	Urban population share or urban growth rate	May influence tourism infrastructure and environmental pressure
Energy use	Total energy consumption or energy use per visitor	May decline in intensity; total use may rise through rebound effects

The interaction term shows whether the association between AI and environmental pressure changes with the level of tourism activity, which is one way a rebound effect could appear in the data. If the effect is expected to change sharply once a destination passes a carrying-capacity threshold, a panel threshold model (Hansen, 1999) is an alternative. Propositions 3 and 4 concern visitor concentration, which none of the five models takes as its dependent variable, and testing them requires destination-level measures of overtourism of the kind listed in Table VII.

Table VII lists possible measures for each variable. The choice should follow data availability, the research question and the level of analysis. A country-level study can use national tourism and technology indicators, while a destination-level study will need visitor density, congestion and environmental-monitoring data.

X. POLICY IMPLICATIONS

Governments need to integrate AI into their sustainable tourism plans and not as an end in itself. Tourism technology policy should be tied to environmental goals, to the carrying capacity of the destination, to the jobs and welfare of local communities, and should consider the effectiveness of investments in AI in terms of measurable outcomes: productivity, service quality, and resource efficiency and distribution of visitors. All tourism businesses must disclose their overall energy consumption, water usage, waste and emissions and efficiency ratios. This enables to reveal the rebound effects and to prevent firms claiming relative efficiency improvements as evidence of overall sustainability.

Monitoring can be useful only when it is connected to clear thresholds, clear responsibilities and enforcement mechanisms, and is followed by management decisions. Timed entry, alternative-route suggestions, seasonal marketing and real-time congestion messaging can help to ease pressure on popular attractions, and should be based on environmental and social considerations, as well as business demand. If ecological boundaries are exceeded, access restrictions and conservation measures may be required.

Smaller tourism businesses require funding, technical training, joint platforms and digital knowledge services, and employees should be trained in data interpretation, digital communication and in using AI in services to adjust to changes in job requirements. Platforms and businesses need to make clear how their AI systems are collecting data and making recommendations; and authorities can implement transparency obligations and audits to ensure that recommendation systems are not discriminating against less-familiar destinations or smaller businesses. Local communities need to be involved in decisions regarding the development of tourism with the help of AI. Data systems cannot capture congestion, overuse of public services, cultural changes, or environmental issues, while local feedback and public consultation help guide and make visitor-management policies more legitimate. The economic benefits need to be distributed via the local workforce, with SMEs involvement and investment in public infrastructure.

XI. LIMITATIONS

There are 4 major limitations to this paper. Firstly, it is a conceptual synthesis, and it is not a critical narrative review, it does not undergo a systematic review of the literature, where the research question is predetermined, and a database search is conducted. Second, it considers AI as a single entity but there are many different categories of AI, machine learning, generative AI, robotics and predictive, which have varying uses and consequences, and the field is very dynamic. Third, the link between AI and sustainability is contextual. The results of big hotel properties or technologies in the advanced economies or well-developed destinations cannot always be extrapolated to small businesses or destinations that have limited infrastructure. Fourth, reliable and comparable data is needed for the proposed models. The extent of AI adoption is difficult to consistently measure across countries and companies, and there is a need for more indicators to differentiate between basic digitalization and actual AI use. In addition to the aforementioned issues in Table V, one question must be given highest priority: Does environmental regulation and institutional quality, together with visitor-management systems, mitigate the risk of overtourism becoming more intense with the aid of AI?

XII. CONCLUSION

AI is transforming the tourism economy. Making use of predictive analytics, personalized recommendation, automated services, intelligent pricing and data-driven management can boost productivity, foster innovation and enhance the competitiveness of tourism enterprises. It is tougher to make the case for sustainability. While AI can contribute to energy efficiency, water conservation, waste reduction, sustainable transport and monitoring of biodiversity, the reduction of the amount of energy, water, and waste consumed per visitor can be compensated for by an increased number of tourists. AI does not guarantee sustainable tourism; this is the argument of this paper. The outcomes are a function of the interaction of technological capability, economic incentives, institutional quality, and environmental regulation and social participation. Some of the best use of AI is to regulate visitors, secure natural assets and enhance local welfare and to boost demand and revenue. Policymakers and businesses should therefore look at economic performance as well as the environmental indicators, carrying capacity of the destination, employment quality and the well-being of the community, and future research should provide more robust empirical evidence for nonlinear relationships, rebound effects, and the role of governance. The purpose of applying AI to tourism should be an economy that is more productive, more inclusive and less damaging to the environment. That's not what maximizing visitor growth with technology will do.

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