brand published a post on Instagram (see Figure 1) stating: "Through artificial intelligence and the help of @joooo.ann, we have been able to enter new and unexplored worlds, showing our Puglia in a surprising light and making comfort an almost visible and tangible sensation." In other words, AI seems to support Natuzzi's communication in creating and delivering communications to consumers. However, how professionals perceive and behave towards AI to develop and manage their communication marketing strategies and how AI helps or threatens them in communicating with consumers is even less studied.

Despite the numerous benefits highlighted, the use of AI can lead to substantial changes in organizational terms and internal processes (Langer and Landers, 2021). In fact, while there is an expectation of greater effectiveness and efficiency in both analysis and marketing communication planning, the use of AI requires a review of organizational processes and workflows, as well as the acquisition of new skills by the professionals who will adopt it (Tschang and Almirall, 2021). However, research aimed at understanding the changes brought about by AI in the practices of marketing and communication managers is still limited. Therefore, this study investigates managers' perceptions, behaviors, motivations, and environmental influences toward implementing AI in and for marketing communication strategies and campaigns adopting the SCT.

The study adopts a qualitative approach, focusing on Made in Italy companies in luxury furniture design. The decision to focus on managers in Made in Italy enterprises stems from three primary motivations: (a) the expansion of luxury furniture design exports, which increased by 13.4% in 2022 compared to the previous year, leading to a sector sales volume of 1.9 billion euros (Intesa Sanpaolo, 2023); (b), the strong tradition of Italian enterprises in creating high-quality luxury furniture design product (Codignola, 2018), and the global appreciation and awareness of the Made in Italy luxury furniture design (Future Classics Furniture, 2023); and (c) national institutional investments towards the digitalization of Made in Italy sector enterprises, aimed at fostering the adoption of new technologies and promoting innovation (Ministry of Enterprises and Made in Italy, 2024). Additionally, Made in Italy companies are known for their strong identity and pronounced creativity; thus, the study of AI by marketing and communication managers within these organizations represents an original lens through which to interpret the phenomenon.

Figure 1 – Instagram post by Natuzzi, January 20, 2024
Original post: https://www.instagram.com/natuzzi/p/C2VJxWHoYLO/?img_index=1

Purpose of the paper. *Based on the above background, the study aims to understand how communication and marketing managers perceive AI and how they deal with this technological tool. The study focuses on managers working in the luxury furniture industry. Therefore, the research seeks to understand managers' perceptions about the benefits and risks related to the introduction of AI in defining and creating marketing communication strategy; attitudes, exploring their beliefs, concerns and expectations, motivations for adoption, and implications of organizational, work processes and skills needed for the introduction of AI.*

Methodology. *Given the exploratory essence of the research, the current research adopts a qualitative approach. Marketing and communication managers will be considered key informants for the study (Barker et al., 2005). The authors will select those respondents who are (a) employed as marketing or communication managers in a luxury furniture design enterprise based in Italy and (b) involved in defining the marketing communication strategy for their companies.*

The data collection will be assessed by conducting in-depth semi-structured interviews. In-depth semi-structured interviews let researchers obtain relevant information related to respondents' experiences and perspectives (Leavy, *2020). According to the SCTOM theory, the semi-structured interview outline will investigate the three interrelated factors (Behavior, Cognitive and other personal factors, External environment) underlying the causal interrelationships of managerial decisions.*

All in-depth interviews will be conducted in Italian through digital video call platforms (such as Google Meet or Zoom). The choice of using digital video call platforms is justified by two main reasons (Irani, 2019): (a) the ability to interview managers from different geographical areas than the researcher; (b) the greater flexibility offered by digital platforms in scheduling interviews; and (c) the platform's capability to record audio after explicit consent for recording is obtained from the interviewee. Each interview will be transcribed using software and subsequently checked by the authors for content accuracy. Then, each author will proceed with manual coding (Saldana, 2021) to identify the main themes and connections among them (Braun and Clarke, 2006).

Results. *The research is still in progress. We are currently experiencing a period when AI is gaining global attention for its rapid development, drawing the interest of scholars and practitioners seeking to capture its implications, advantages, and disadvantages. Through this exploratory study, we expect insight concerning attitudes, expectations, and influences managers perceive and face when adopting and integrating AI into their practices to define and implement communication strategies. With our research, we expect to contribute to the discussion of AI and analytics in the management context (e.g., Kanbach et al., 2023), demonstrating how SCTOM can be adopted to investigate AI adoption.*

Research limitations. *Like other research endeavors, this study exhibits certain limitations that, on the one hand, efforts will be made to mitigate during the research process. On the other hand, they may serve as starting points for future investigations.*

Firstly, the study aims to understand marketing and communication managers' integration of the inclusion of AI for defining and implementing marketing communication strategies in luxury furniture design companies labeled as "Made in Italy." Despite the increasing adoption of AI in businesses worldwide, Italy shows a positive trend of AI inclusion, primarily among large enterprises (6 out of 10 have at least one active AI project). In contrast, only 2 out of 10 small and medium-sized enterprises integrate AI (Osservatorio Artificial Intelligence, 2024). Consequently, the research might focus on managers working in large enterprises. Researchers will attempt to limit the effect of this limitation during the data collection process.

Secondly, the research analyzes the Italian context, considering the global appreciation for furniture designed by Made in Italy organizations. Therefore, the study focuses on this geographical and cultural reality. Consequently, the results may not align with managers operating in other European or non-European territories.

Thirdly, when writing the current manuscript, the European Union approved the AI Act, thus becoming the first organization globally to impose regulations on the use and dissemination of AI (European Commission, 2024). Therefore, many of the activities conducted by managers up to this point may experience some slowdown due to the need to comply (if necessary) with the regulations. Hence, the study may reflect a transitional situation, and future research may adopt a longitudinal perspective to analyze any repercussions resulting from regulation.

Finally, the research is qualitative, characterized by data collection based on in-depth interviews with managers. The qualitative nature of the research does not favor the generalizability of the results. Therefore, future research may adopt the results for questioning to confirm their validity.

Managerial implications. *The study aims to offer a series of significant implications for professionals across various sectors. Firstly, it seeks to understand the perceptions and attitudes of communication and marketing managers in the luxury furniture design sector of Made in Italy toward AI. This will provide top management and entrepreneurs with a framework to identify areas for improvement or challenges to maximize the benefits of AI adoption within their organizations. Secondly, the investigation aims to provide AI service providers and developers with necessary insights into the current usage of AI within luxury furniture design enterprises of Made in Italy. This will enable them to pinpoint areas where they can offer enhanced solutions or new services to meet clients' needs in marketing strategy. Finally, the analysis aims to provide Italian institutions and policymakers with an overview of the current AI usage among managers of Made in Italy luxury furniture design enterprises to identify actions that can promote their growth and innovation within the context of the digitalization of the Italian economy. These implications are crucial for fostering progress and competitiveness in the Italian luxury furniture design sector, considering the Italian government's effort to promote Made in Italy productions (Ministry of Enterprises and Made in Italy, 2023).*

Originality of the paper. *The study is among the first to focus on how marketing and communication managers in the luxury furniture design sector perceive and behave toward AI for defining, integrating, implementing, and activating marketing communication strategies. Specifically, the research seeks to depict and adopt the SCTOM theory, the current state of AI adoption, and how this tool fits into the activities of marketing managers and all parties involved in defining marketing communication strategy. Therefore, in theoretical terms, the research aims to advance knowledge regarding the relationship between AI and marketing and communication managers; in managerial terms, it aims to provide precise guidance by creating a toolbox immediately usable by managers.*

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Artificial Intelligence in SCM: insights from two illustrative cases

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Abstract

Artificial Intelligence (AI) and Supply Chain Management (SCM) have gained increasing attention in the last few years. Many literature review papers address the issue and highlight the importance of deepening the interplay between AI and SCM. The different contributions offer together a double faced picture of such interplay. On the one hand the opportunities stemming from AI applications in SCM are emphasised. On the other hand the future of such applications has still undefined contours and poses important challenges. In this work-in-progress paper we try to analyse this ongoing scenario from the perspective of two firms engaged in the introduction of AI in two different positions in the Supply Chain (SC). The main aim of this paper is explorative and is that of understanding the main constraints and opportunities that a firm meets when it attempts to integrate an AI tool in the context of a bundle of resources (both tangible and intangible) that have been already settled for a specific purpose. Notably, we assume that AI is not in a vacuum and AI applications require an integration with other resources in the company's SC, in order to exploit its potential and to limit possible negative effects on the overall performance. From this perspective, the two cases offer interesting insights that will constitute the basis for the refinement of the research design and for the framing of more specific and bounded research questions in such a domain.

Key words: *AI; SCM; CRM; IoT; Operations Management*

Framing of the research. *SCM is a comprehensive term that encompasses the end-to-end management of processes involved in the production and delivery of goods and services along the SC. It includes the coordination and integration of various activities, including procurement, production, transportation, and distribution, to create value for the end consumer. In particular, SCM embraces activities related to both physical and information flows, together with the alignment of organisational and network dynamics (Stock et al., 2010). Therefore, the primary aim of SCM is to coordinate, monitor, and control processes to achieve integration (Power, 2005; Kaufman, 1997).*

The advent of Industry 4.0 (I4.0) has pushed transformative changes in SCM, leveraging advanced technologies such as the Internet of Things (IoT), big data analytics, or automation. Companies have now the chance to exploit the application of I4.0 technologies to SCM in order to achieve a series of benefits, including increased visibility and transparency among actors, enhanced data-driven decision-making processes, optimised operations, warehousing, and logistics, and more collaborative SC networks (Seyedghorban et al., 2020; Kache & Seuring, 2017).

One notable area of impact is the integration of AI into SCM processes. Such technology can be defined as "a field in computer science encompassing the development of systems capable of performing tasks that normally necessitate human intelligence" (Pournader et al., 2021:2). Therefore, AI in the context of SCM refers to the use of intelligent algorithms and machine learning to enhance decision-making, optimise operations, and improve overall efficiency within the supply chain. Given the substantial potential that AI encompasses in terms of improving operations along the SC, together with collaboration and overall performance, business companies are showing interest in the topic, which also constitutes a flourishing research stream (Toorajipour et al., 2021).

Available literature on AI and SCM shows how this research topic is wide and can be faced through various lenses and focal points. Just to provide some examples, Toorajipour et al. (2021) address the main benefits of AI in the SC and highlight the operations and tasks that are more likely to be further improved in the next future. Helo and Hao (2022) embrace the topic from the business model perspective, empirically investigating the AI-based digital transformation of four case companies to identify the main areas of value creation in the SC. Similarly, the work of Sharma et al. (2022) presents an overview of AI- and SCM-related literature to unveil some crucial research clusters, including network design, supplier selection, inventory and demand planning, and green practices.

Despite the growing attention to AI in SCM literature, there remain open points that warrant further investigation, as underlined in all the above-mentioned studies on AI and SCM. Future research streams include - but are not limited to - the exploration of how AI can support SC integration, the synergies that could arise from the combination of AI and other I4.0 technologies such as Industrial IoT or Blockchain, the potential application of AI for logistics optimization, the

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impact of AI in the network orchestration, especially where interactive decision-making processes are activated, the combination of AI with Big Data Analytics and CRM system (Toorajipour et al., 2021; Ledro et al., 2022). Areas of interest also extend to the deeper understanding of the contribution that AI can bring to SC capability and competitive advantage (Pournader et al., 2021), as well as to SC resilience, knowledge-building, and performance (Sharma et al., 2022).

In particular, this explorative research undertakes what Richey Jr. et al. (2023) indicate as the 'Level 2' in their framework for researching AI in the SC: discovering the challenges and benefits of AI to SCM in terms of practices and processes. This level of analysis underlines the need for future research addressing how AI modifies internal SCM processes, including reconfiguration, innovation, and decision-making, as well as collaborations and coordination within external relationships.

Taking a more micro perspective on the studies in this context, it emerges that many companies are focusing on optimising isolated parts of their processes through the specialistic use of AI, leading to integration challenges and short-term vision limitations within the SCM framework. Despite a diffused silo-thinking approach and modest investments in AI - mainly to adapt to evolving market dynamics, the necessity of reevaluating long-term AI-based integration strategies is emerging. This necessity is clearly underlined from the international consultancy agency Accenture, which poses the attention on how properly addressing AI means "approaching generative AI not merely as the latest in a long line of software implementations, but rather as an enterprise transformation, with a clear focus on end-to-end business capabilities and implications for areas like data, people, ways of working, processes and responsible adoption" (Rey-Marston & Lagunas, 2024:4). Such integration efforts are pivotal to achieve enhanced efficiency across the overall SC, paving the way for a more sustainable competitive advantage. In this perspective, resources acquire a great role in leading the AI-driven transformative change (Chen et al., 2022). Embracing a holistic approach to the analysis of the resources involved in the overall process can be of help in overcoming the silo-thinking approach in favour of a more integrative view.

Therefore, the present work seeks to contribute to the existing body of knowledge by focusing on the intersection of AI with two activities upper and lower in the SC: operations management - meant as internal logistics - and Customer Relationship Management (CRM). The goal is to shed light on unexplored aspects and offer insights into the evolving processes underlying SCM in the context of AI-driven advancements.

Purpose of the paper. *The main objective of the paper is to explore the problems and opportunities of integration of AI in the SC when other resources interact with AI - and each other. Specifically, the paper aims at understanding the main constraints and opportunities that a firm meets when it attempts to integrate an AI tool in the context of a bundle of resources (both tangible and intangible) that are already settled for a specific purpose in the SC. Notably the two cases are focused on two different AI applications in two different positions in the SC (mainly centred on operations management). The overall aim of this contribution is to achieve a clearer definition of specific RQs and at a refinement of the whole research design.*

Methodology. *The paper is in its seminal phase of development. Here we offer two illustrative cases developed with a qualitative approach and data collected from different sources: first sources of data are explorative direct interviews and already collected data for other research purposes in each of the two companies; secondary sources are constituted by the analysis of internal company's documents, company's websites, press releases. The first case of Alpha (a medium-large furniture manufacturer) shows the first steps of a project of implementation of AI in the optimization of the maintenance, problem fixing and problems reporting (ticketing) processes of the whole production plant in the core production facility. Alpha has the main objective of making the most by data stemming from the different machineries (IoT) and other sources (opening of tickets by operators with QRcode technology) conveying in a centralised dataset and managed by an ad hoc software developed in interaction with a partner (supplier). The second case of Beta (a large manufacturer) is about the adoption of AI in the CRM system of a company in the mechatronic sector. Beta has the main objective of exploiting AI to support customers that require assistance by providing automatic answers and teaching customers how to solve specific problems without the need of a technical intervention. An AI tool is integrated in the CRM system to access a set of technical documentation and provide customers with personalised feedback. Not only, AI is also adopted within the CRM to facilitate and accelerate the desk activities of assistance contact centre operators.*

In the data analysis process we rely on the Resource Interaction (RI) approach developed by IMP (Industrial Marketing and Purchasing Group). In particular, the RI perspective highlights the interactive nature of resources and emphasises the potential (and value!) of a resource "only" in interaction with other resources (Baraldi et al., 2012; Bocconcelli et al., 2020); RI framework has been often used in IMP-related literature to deal with the complexity of technological development in a networked context (Chou & Zolkiewski, 2012; Håkanasson & Waluszewski, 2002).

Taking into account the assumptions of the RI and related analytical frameworks (Prenkert et al., 2022) allows us to disentangle the complexity of the interplay between AI and SCM. In particular, we claim that by analysing AI as a resource that needs to be exploited in interaction with other resources (other digital resources as well as other tangible and intangible resources) can offer a more real picture of the process of implementation of AI that, in our view, could present a variety of multifaceted "dark sides" that are mostly neglected by literature and managers.

In the future development of the research we will rely on a qualitative approach and on the IMP RI framework, too, in order to address the RQs that will stem from this preliminary analysis.

Results. *Illustrative case one: Alpha and AI in the optimization of maintenance and interventions in the production plant. Alpha is a manufacturing company in the furniture production sector, located in central Italy. Alpha has known a huge development in the last ten years both from a market perspective and a technological perspective. Taking the latter,* *the company made huge investments in the last years and reorganised the whole production processes and logistics. A new and advanced factory has been settled up which constitutes the productive lung of the whole production. The factory is made up of two integrated and highly automated plants: one with a more flexible "vocation" the other one characterised by high volumes and standardised components (for a high variety of products range and lines). The machineries in the two plants are highly automated and robotized (especially in the "flexible" one) and equipped with sensors, IoT technologies and digitised workstations for operators. The investments in the production plants are constant and incremental, with solutions introduced in different times in the very last years mainly addressed to implement I4.0 solutions. In the last year the company faced the issue of optimising machinery maintenance procedures, and problem signalling and resolution processes. The different machineries and the two plants are handled by a central management software developed by a partner supplier. The software collects and processes data that comes from different sources: IoT sensors, control units of CNC machines, operators' reports on the functioning of plants and machineries based on QR code and mobile technologies, and other management software systems.*

A huge amount of data needs to be handled and, most importantly, AI seems to offer the opportunity of making a more integrated use of it. The Director of Production of Alpha, together with the software supplier, proposed to the CEO to start a project of AI introduction to overcome inefficiencies met in the last year due mainly to the overhead of information to be handled and processed in order to promptly solve (and anticipate) production problems. Another motivation pushes the Production Responsible to sponsor the AI project: that of using in a more effective way the different data collected and processed; in his view, AI applications could contribute to exploit the value of data beyond operations management efficiency, for example in relation to supplier management and/or market management. But this is another story; in fact, since the beginning of the project it appears clear that the only introduction of AI in the optimization of the operations in the process of maintenance and controlling of the production plants was per se an enormously ambitious project. In fact, from a first analysis conducted by Alpha and the software supplier it emerges the difficulties to clearly map the prerequisites and trace the scope of the project, due to the variety of resources in play.

The project has been thus limited to two main interrelated and sequential outcomes: a) the use of AI applications for the "tickets' normalisation"; b) the use of AI for suggesting a solution to the problem "opened" by a ticket by an operator or signalled by IoT and workstations. In relation to the first objective Alpha has the problem of standardising the language used by operators in the problem signalling in a specific area of the user's interface system. Each human (operator) used so far natural language in this process to describe the problem. And, of course, each operator had his/her way to describe it. The result is a huge variety (both intra- and inter-personal) of describing the same problem and of problems signalled. The idea is to use AI (i.e. Large Language Models - LLM) for communicating in a standardised way the signalling of the problem. This (simple) objective is taking a considerable amount of time for being defined, designed and implemented because it involves: i) the "normalisation" of the Alpha dataset; ii) the analysis and refinement of the dataset to be used for AI training; iii) the selection of AI tool available in the market (ChatGPT by OpenAI or Gemini by DeepMind-Google or Llama by Meta, only to make some examples) and the use of the relative API (Application Programming Interface) that could "dialogue" with the management software and the AI tool; iv) the involvement of operators.

The first objective is apparently necessary for the second one (AI suggesting a resonated list of solutions for the problem), however some analysis has been already conducted in relation to the possible resources involved in the second step. A first problem here is linked to the fact that in this case, AI tools available in the market are very few and most of them do not fit for the specific purpose and it seems, right now, that an ad hoc AI program should be developed with the collaboration of the supplier.

Alpha, soon realised that the project cannot be conducted alone, and asked for the collaboration of the local University, Department of Computer Science. The idea is to apply for a regional funding call with a large partnership involving the University, the partner supplier and other companies in the Region.

<u>Illustrative case two</u>: <u>Beta integrating AI in CRM</u>. Beta is a prominent mechatronic company specialising in the global production and distribution of industrial woodworking machinery. In 2016, the firm invested in a Digital Servitization business model by integrating advanced digital services into its offering through the adoption of the IoT technology. A portion of Beta's revenue is derived from selling such digital services.

Since 2008, Beta has employed a customised CRM system to meticulously manage customer-related data. This highly tailored CRM is organised in two areas - Sales and Services - and provides valuable information to both sales representatives and service assistance experts. Via the CRM system, Beta can access key information and KPIs on customers, answer assistance calls from them, plan technical interventions both remotely and on site, and much more. Notwithstanding its efficacy, the current utilisation of the CRM system poses challenges due to an intricate assistance workflow, propelled by a considerable customer base and human resource constraints in the Service department. Indeed, to properly work with the CRM, a consistent effort is required in terms of employees; the CRM simplifies some activities while necessitating continuous human supervision and activity.

In response, Beta has initiated a project to incorporate AI into its CRM system. The project entails two expected outcomes. The first is a visual box in the CRM dashboard that operators can access in real-time to support the telephonic assistance flow and improve market analyses. The second one is the creation of a chatbot that customers can access via the log-in into the IoT application, which is able to send customers text answers, technical files, or registered videos indicating the solution to the problems they raise. Therefore, several applications of AI are requested to comply with the project: Vision, Speech Recognition, Natural Language Processing, and Planning & Scheduling (according to the *taxonomy proposed by Pournader et al., 2021). The AI integration aims to expedite response times, address technical issues proactively, and minimise the need for on-site interventions, thereby enhancing overall efficiency and efficacy.*

Despite the potential benefits of AI implementation, Beta is encountering some challenges along the way. A first problem concerns the difficulties in connecting two different AI systems - coming from different providers - into the CRM platform. Indeed, the aim of Beta to create two interfaces based on AI, one within the CRM for internal purposes and one within its digital channels to communicate with customers, has led the firm to adopt separate AI technologies. In particular, for the CRM add-on tool, Beta is negotiating with the CRM provider itself, which recently developed an AI-based module to be used within the platform. For the chatbot, instead, Beta is collaborating with a small start-up providing AI models. The main difficulty resides in the fact that the dataset needed for both AI technologies should be organised based on the requirements of the AI providers, while guaranteeing their interface in the CRM platform linked to the cloud.

A second challenge that Beta is facing, strictly linked to the previous one, regards the development of a proper knowledge base, with a specific structure that satisfies the requests of the AI providers. To work properly, both AI for the CRM add-on tool and for the chatbot should source information from a coherent and organised database. The need for a structured documentation system is posing a significant hurdle for Beta, especially considering that until now the firm left to each technical expert the responsibility to create and manage his/her own dataset of information. This means that the existing technical documentation contains different typologies of files with various personal styles and without any formatting or content constraint. Even though Beta planned a documentation revising activity while designing the AI projects, it has definitely underestimated the number of human resources, time, and effort needed. Only two people were initially dedicated to this activity; this is not economically sustainable for Beta, which is now aware that completing the activity with such a limited resource availability will take years.

Additionally, to further complicate the AI implementation is the process of learning that the AI technologies should accomplish when introduced in a new industrial context. This intricate process involves, for instance, acquiring a highly specific lexicon, decoding Big Data - particularly those coming from the IoT platform, and learning how to provide customers with replies that are reliable and in compliance with regulations in force for each country worldwide.

Finally, Beta is currently struggling in finding the right communication strategy toward the market. The company is aware that potential resistances from customers could emerge regarding the introduction of an AI-based touchpoint such as the chatbot. The new touchpoint may alter the accustomed human-centric relationship dynamic and somehow destroy value that, for some customers, was inherent in human interaction.

Some preliminary observations can be drawn from the two illustrative cases. A first, general consideration relates to how Alpha and Beta are a clear demonstration that AI entails a great potential in transforming operations management along the SC, with implications both upstream and downstream. However, the two cases also underline that achieving benefits from AI is far from easy. It requires going through a non-linear process, where the expected optimization in terms of both efficiency and efficacy could be undermined by a highly resource-consuming implementation journey. Indeed, the resources in play are many and different and, in most cases, more in quantity than initially expected.

The experience of Alpha and Beta also allows us to observe that a complex network of actors is in play when considering AI. On the one hand, inter-organizational relationships with a constellation of suppliers greatly impact the overall competence of the firm to effectively apply AI within its SCM operations. On the other hand, properly managing the relationship with customers is crucial to reduce, if not avoid, resistances to change and value destruction. Finally, and in relation to the previous point, a common mistake of companies involved in AI implementation is conceptualising such technology as an overarching tool able to solve varied problems; the cases shed light on a missing clear vision of the goals underlying AI, the actors to involve, the resources to adopt, as well as the activities to implement. A fragmented approach to AI along the SC is the most prevalent approach so far.

Research limitations. *As we highlighted, this paper is exploratory in nature. The main aim in this phase is to pave the ground for future research relying on insights stemming from the two cases. Notwithstanding this approach, the study here is not without intrinsic limitations. A first limitation is related to the data collected that are quite different in terms of amount and quality in the two cases. In the case of Alpha we had the opportunity to make only a few interviews so far, and the project of AI implementation is in its initial phase. In the case of Beta the process of AI introduction is more advanced and we had the opportunity to interact with the company in a more intensive way for this study and to rely on a large amount of data that we collected in the last five years for other research purposes.*

Managerial implications. *We believe that this research, taking into account the bundle of resources already in play in a given industrial context, and analysing AI as a resource to be integrated in it, could provide important insight to companies involved in integrating AI in their SC.*

Some possible contributions with the proceeding of this research, follow. Firstly, an accurate and preliminary mapping of the network of resources in play (both tangible and intangible) seems to be crucial in the cost-benefit evaluation, in the design of the integration process, as well as in the effective exploitation of AI potential. Resources present interfaces that are not easy to change and adapt, and a change in one interface to adapt to a new introduced resource (AI), can cause problems in other resource interfaces with additional costs for the company. Secondly, AI big players and their products currently present a standardised way in facing the market and the customers, that is not aligned with specific company's needs (this is especially true for smaller companies) that are struggling with finding more flexibility and adaptation in the use of AI solutions in their specific resource bundle in the SC. In this respect, other actors - in an inter-organizational perspective - will play a major role in these processes, i.e., Universities, IT business solution providers (see, for example Accenture), institutions, IT platforms, logistics platforms, etc. It becomes thus important for *companies to select the right partners to pursue the objective of AI integration in the SC. This also implies - in an intra-organizational perspective - a profound revision of the capabilities of people involved in the process within the firm, who have to be ready to mediate with those actors and each-other.*

Finally, and linked to the previous two considerations, the initial stage of AI implementation seems to call for an incremental approach, where different suppliers and technologies are evaluated and tested, until the best solution is found. Considering that this initial step can last a consistent time, firms could exploit this time to develop a long-term vision for AI applications, in order to adapt the initial efforts to further expansion of AI along the SC. To do this, it is paramount to find the best fit between the actors involved and the resources requested to implement the AI solutions in consideration. Indeed, with the right partners and powerful AI infrastructures, it could be possible to invest on a wider project of conjunct optimization of the entire SC and its management, therefore balancing the trade-off between AI costs and benefits and truly exploring increased efficiency and efficacy.

Originality of the paper. *The paper offers an original perspective on the relationship between AI and SCM in the operation management domain, in the light of its focus on resource interaction. Considering AI and AI-related solutions and tools as a resource in itself - and not "simply" a panacea - that has to be integrated with other resources, provides a different angle of analysis that could contribute with its future development to the debate around the possible future of AI contribution in the companies' SCM projects implementation.*

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Strategic Foresight and Artificial Intelligence: Evidence of a Paradoxical Relationship

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Framing of the research. *Amidst the dynamic landscape of today's business environment, where change is constant and unpredictable, the need for strategic foresight – "the application of futures and foresight practices by an organization to advance itself" (Gordon et al., 2020, p. 2) – is paramount. Companies, driven by the imperative to innovate and stay competitive, must adopt proactive approaches to anticipate future events (Bell, 1997; Iden et al., 2017; Tapinos and Pyper, 2018). Indeed, innovation is not a spontaneous process that magically happens but instead a process of evolution with design, with leaders needing to play a role in cultivating and fertilizing innovative behavior throughout organizations (Scott and Bruce, 1994; Leavitt, 1996; Yuan and Woodman, 2010). Relatedly, scholars consistently credit foresight practices, such as future thinking and scenarios (De Smedt et al., 2013; Eisenbart et al., 2022), not only expanding the range of futures under consideration but also aiding in identifying more effective innovations (Kameoka et al., 2004). As organizations grapple with the challenges of the contemporary world, the interplay between strategic foresight and innovative behavior emerges as not merely desirable but essential for sustained success (Bradfield et al., 2005; Chermack, 2005; Burt and Wright, 2006; Rhisiart et al., 2015). Prior research has delved into the contextual precursors of innovative behavior, such as organizational climate, and underlying elements, like cognitive style, openness to experience, creative personality, and self-efficacy (Vecchiato, 2017; Kwon and Kim, 2020; Cristofaro et al., 2022; Marchiori et al., 2022). While existing literature acknowledges the central role of mental models in fostering innovative responses, there are far fewer studies that explore the cognitive processes and strategies that can stimulate managers' ability to see and sense the future and, hence, their innovative behavior (Burt and Nair, 2020; Eisenbart et al., 2022).*

Purpose of the paper. *Despite foresight and innovation research underscoring the importance of anticipating the future for reaching effective innovations, significant gaps remain in identifying factors affecting the relationship between them (Gordon et al., 2020, p. 8). Only recently, some scholars theoretically advancing a positive effect of Artificial Intelligence (AI) on foresight efforts have taken steps in this direction (Schühly et al., 2020; Truong and Papagiannides, 2022; Bahoo et al., 2023; Dwivedi et al., 2023), but with only little empirical test. Thus, a gap exists in understanding how foresight can successfully leverage AI to stimulate innovative behavior (Gordon et al., 2020, p. 8).*

The literature recognizes that foresight's primary outcomes in organizations are various forms of innovation, demonstrating how scenario thinking can lead to identifying new opportunities and as a precursor to product innovation (Worthington et al., 2009; Sarpong and Maclean, 2011). Indeed, in the context of a more appropriate response to a changing environment, a relevant topic is also the relationship between foresight and company performance, which, according to a study by Rohrbeck and Kum (2018), is a positive relationship and reveals that companies prepared for the future have a higher probability of outperforming the industry.

Moreover, Yoon et al. (2020) developed a model linking foresight, organizational learning, and innovation. They found that the relationship between foresight and organizational learning is moderated by integrative capabilities, and the level of integrative capabilities conditions the indirect effect of strategic foresight on innovativeness through organizational learning. Recently, Schwarz et al. (2023) explored foresight methods among design thinking professionals, analyzing their adoption of techniques that anticipate future customer needs and emphasize emerging technologies. They found positive correlations between foresight methods and their contributions to project success. Schwarz et al. (2023) concluded that the toolbox of design thinkers should also be expanded by prevalent methods from foresight, particularly trend research or scenario planning. In these discussions, the positive benefits of foresight activities are based on the hard work and cognitive efforts of decision-makers. Therefore, our baseline hypothesis is the following:

H1: Strategic foresight positively influences innovative behavior.

Furthermore, attention to AI has grown among researchers and industry experts over the past years (e.g., Gao et al., 2021; Del Giudice et al., 2023; Haefner et al., 2021; 2023) because it allows computers to emulate human brain activities

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like reasoning, learning, and planning, thereby addressing complex challenges, formerly the domain of human experts (Lei and Wang, 2020). Specifically, AI empowers machines to learn, process, and utilize knowledge for task performance, uncovering or tapping into knowledge that can be conveyed to humans to bolster the decision-making process in an organization (Cerchione and Esposito, 2017; Camarillo et al., 2018; Grzonka et al., 2018; Vajpayee and Ramachandran, 2019; Dwivedi et al., 2023). In particular, AI bolsters companies' ability to conduct intricate quantitative and qualitative data analyses, thereby enhancing their modelling procedures (Keller and Heiko, 2014, Heiko et al., 2015). This capability facilitates the discernment of uncertainties in the current and future environment, paving the way for the systematic identification of potential opportunities and risks (Nascimento et al., 2021; Jabeur et al., 2022).

Conversely, it is worth pointing out how AI can cause information overload, namely, when a person receives too much information or, more specifically, when the input exceeds processing capacity (Ferguson et al., 2022). Some have also warned against the possible detrimental effects of AI on cognitive processes and skills: when trying to substitute deep reflection and learning with AI, the benefits of efforts that lead to critical and innovative thinking and holistic problem-solving skills are lost (Yu, 2023).

Moreover, while foresight activities due to cognitive efforts and benefits of prospective thinking can lead to more innovative behavior, substituting those cognitive efforts with technology, and AI in particular, could accelerate or negate some benefits. Accordingly, we derive the following hypotheses:

H2a: High or no use of AI during foresight will negatively influence the relationship between individual foresight and innovative behavior.

H2b: Moderate use of AI during foresight will positively influence the relationship between individual foresight and innovative behavior.

Methodology.

Research Design. *In this study, an experimental design to test hypotheses has been adopted. This method is considered valid for fields of research that have largely passed the nascent stage of development (Edmondson and McManus, 2007), as is the case with future studies and innovative behavior, as established by a few literature reviews (Iden et al., 2017; Kwon and Kim, 2020). Moreover, we can draw more confident conclusions about the causal relationships via an experiment by manipulating the independent variables and observing their effects on the dependent variable – also in line with the recent call for more experimental design in strategic foresight research by Derbyshire et al. (2023) to improve the scientific basis of futures and foresight research.*

We adopt a between-group design with a 2x3 factorial between-subject experimental design. In a between-group design, participants are divided into groups (conditions), and each group receives a different condition or treatment (Montgomery, 2017). In this case, we have multiple experimental and control groups representing other conditions. The 2x3 factorial between-subject experimental design indicates that we have two independent variables, each with three levels. The two independent variables in this design are 1) Foresight (Level 1, Present: participants receive the foresight prompt; Level 2, Absent: participants do not receive the foresight prompt), and 2) AI usage (Level 1: No use; Level 2: Moderate use; Level 3: High use). Combining the levels of both independent variables, we create the different experimental groups (introduced later). This factorial design allows us to examine the main effects of each independent variable and the interaction effect between them. By comparing the outcomes across the different conditions by conducting a two-way ANOVA, we examine the influence of foresight, AI use, and their combined effects on innovation outcomes.

Participants and Procedures. *We recruited 252 professionals with practical experience establishing market potential for new products through convenient sampling. This was possible thanks to the Placement office of the Faculty of Economics of a leading University in Italy. These participants graduated from the same business school, completing an honors degree program in management.*

Since we aim to investigate the impact of foresight prompts and different levels of AI usage on participants' generation of innovative extensions for a specific project, we formed four groups of equal numeric composition (i.e., 63 each). Three of them were prompted, before generating innovative product developments, to make strategic foresight for the company offering that innovative product. In particular, the prompt asked to envision the future landscape of the company offering the proposed innovative product over the next decade. Two prompted groups were given access to AI for their foresight, each engaging with the technology at different intensity levels – moderate and high.

We administered an online survey to participants who were asked to be assisted with AI during the experiment. In contrast, we administered a paper-based survey to participants who were asked not to use AI or any other online source. All participants were asked to envision themselves as a company manager focused on pursuing growth opportunities through fostering potential innovation related to a consumer product. They were presented with one product offered by a newly established company in Italy and subsequently required to identify further developments. It is important to note that this product was in its early stages and could be developed further. With a 90-minute time limit, all participants were asked to generate extensions for that specific product and said that the 'best extension' would be awarded. The notion of making the 'best extension' carried out a connotation of competitiveness, further fostered by the promise of a 20€ gift voucher to the top ten performing subjects.

To ensure accurate data collection, participants must enter their extensions as text before completing the survey. This process allowed for a comprehensive examination of the innovative ideas generated by the participants. In brief, the four experimental conditions were:

- *Control Group: No foresight prompt and no AI usage. Participants neither received a foresight prompt nor had access to AI during the product extension generation process.*
- *Experimental Group 1: foresight prompt and no AI usage. Participants received the foresight prompt before the product extension generation process but did not have access to AI.*
- *Experimental Group 2: Foresight prompt and moderate AI usage. Participants received the foresight prompt before the product extension generation process and had access to AI for moderate AI usage.*
- *Experimental Group 3: Foresight prompt and high AI usage. Participants received the foresight prompt before the product extension generation process and had access to AI for high AI usage.*

To ensure participants' understanding and effective AI usage, we guided accessing and being assisted by the AI language model during the task – ChatGPT in particular.

Measurements. *We initially sourced a product from Kickstarter's renowned crowdfunding platform. By selecting products from such platforms, we ensured that the idea presented was in its early stages of development, requiring additional funding and refinement before it could be successfully introduced to the market. This methodology aligns with prior studies recognizing the comparable evolutionary state of ideas pitched through crowdfunding (Kornish and Ulrich, 2014). In this study, we introduced participants to a project centered around a new vacuum cleaner, the Skadu M1 (product name not provided to respondents). This vacuum cleaner was created by a start-up called Hyper Lychee, established in 2020. All participants will be provided with the anonymized product description obtained from the crowdfunding platform; this information will enable them to envision potential enhancements and developments that can be derived from the initial product.*

Only participants in the experimental groups were presented with short anonymized and pertinent company information taken from Kickstarter, namely, "Company ABC is an Italian start-up set to revolutionize the way people execute daily tasks at home by building technologically and design advanced products to improve the overall quality of life." The Italian context was chosen to allow familiarity with the context. The generated product extensions were evaluated by a team of experts comprising two academic experts in business and management, focusing on new product development, and an external academician who has served as a judge in national startup competitions for the past six years.

To operationalize AI usage, we defined specific guidelines, including the time and number of interactions participants are allowed with ChatGPT. In particular, the following different levels of AI usage were defined:

- *No AI usage: Participants cannot access ChatGPT. They rely solely on their cognitive abilities, knowledge, and experience throughout their innovation-oriented process.*
- *Moderate AI usage: Participants should have at least five and 15 interactions with ChatGPT. This ensures that participants engage with the AI to a certain extent, simultaneously preventing them from excessively relying on AI usage.*
- *High AI usage: Participants should have a minimum of 16 interactions with ChatGPT, with no maximum limits imposed. This ensures a meaningful engagement with AI.*

Group Parity Verification. *We verified the comparability of all groups via a) random assignment, b) verification of participants' mental capabilities to conceive futures and understand cause-effect relationships, and c) AI literacy. Regarding the first, participants were randomly allocated to the different experimental conditions. This approach ensured that each participant had an equal chance of being assigned to any of the conditions, minimizing the potential influence of confounding variables. Using random assignment, the study aims to enhance internal validity and establish more robust causal relationships between the independent variables (foresight and AI) and the dependent variable (generation of innovative extensions). Regarding the second, any differences in the groups' ability to apply foresight could potentially bias the results (Silvia, 2008). Therefore, we analyzed the future extensions generated by the subjects. Finally, we adopted the 12-item scale on AI literacy developed by Wang et al. (2022), utilizing a 7-point Likert scale (Cronbach's alpha 0.83). This allowed us to assess the internal consistency and reliability of the scale in measuring participants' AI literacy in our experiment. On average, participants scored 5.2 on this test (SD= 1.76), thus demonstrating good AI literacy.*

Data Analysis. *The transcripts of all extensions were read independently by two researchers, unaware of the groups they originated from. They then individually coded the extensions using an inductive approach. The codes and criteria were exchanged to ensure clarity in the coding scheme. A final set of criteria was established for coding the extensions. Any discrepancies in the coding results between the researchers were discussed until only a few instances of misalignment remained. Subsequently, a third researcher verified the consistency of each code with the defined criteria. Complete alignment was achieved through a final round of discussion among all coders.*

Results. *To test the proposed hypotheses, a two-way ANOVA was conducted with foresight (present vs. absent), AI usage (no AI use, moderate AI use, high AI use) as the independent variables, and innovative behavior as the dependent variable. According to descriptive statistics shown in Table 1, participants exposed to foresight prompts exhibited elevated innovative behavior ($M = 6.25$, $SD = 1.20$) compared to their counterparts without these prompts ($M = 5.10$, $SD = 1.35$) – in line with Hypothesis H1. Concerning the role of AI, the data revealed that participants who moderately used AI not only had enhanced innovative behavior ($M = 7.20$, $SD = 1.25$) but also outperformed the no AI use ($M = 5.10$, $SD = 1.40$) and high AI use groups ($M = 5.35$, $SD = 1.32$). These observations bolster Hypothesis H2a, where excessive or no AI diminishes the synergy between foresight and innovation. Conversely, Hypothesis H2b is also initially* *supported, highlighting the sweet spot of moderate AI use in accentuating the positive influence of foresight on innovative behavior.*

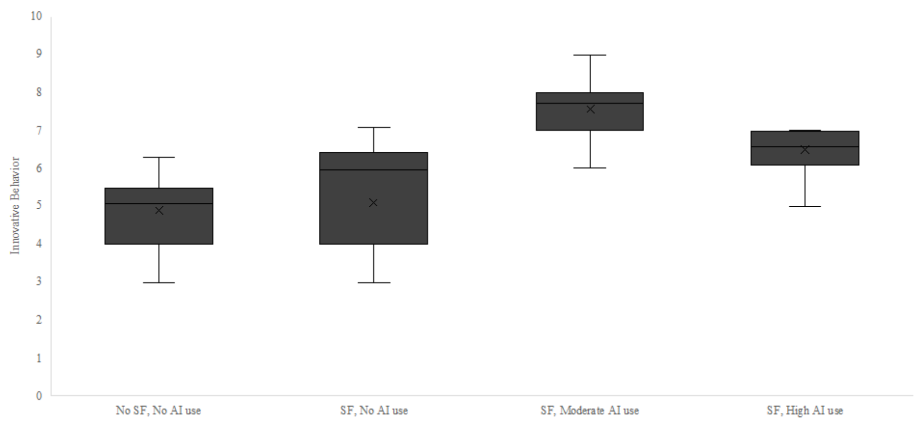
Table 1: Effects of Strategic Foresight and AI on Innovative Behavior

Group	Mean (SD)	F-value	p-value	Effect Size (η^2)
No SF (control)	5.10 (1.35)	8.22	0.451	0.03
SF and no AI use (1)	6.25 (1.20)	14.67	0.001*	0.09
SF and moderate AI use (2)	7.20 (1.25)	9.64	0.002**	0.04
SF and high AI use (3)	5.35 (1.32)	6.31	0.012*	0.03

*Notes: Strategic Foresight. Values within the parentheses represent standard deviations. Correlation significance levels: *p < .05, **p < .01, ***p < .001.*

Further analysis strengthens the above observations. As shown in Table 1, post-hoc comparisons revealed that participants with moderate AI usage [F(1, 246) = 9.64, p = 0.002, η^2 = 0.04] showed a higher level of innovative behavior compared to those promoted with SF and no AI usage [F(1, 246) = 14.64, p = 0.002, η^2 = 0.04] and promoted *with SF and high AI usage [F(1, 246) = 6.31, p = 0.012, η^2 = 0.03]. Thus, a significant interaction effect was found between foresight and AI usage, confirming Hypothesis 1.*

Figure 1: Innovative Behavior Scores Across Experimental Conditions



Notes: SF = Strategic Foresight.

The box plot (Fig. 1) visually encapsulates the interplay between foresight (SF) and Artificial Intelligence (AI) usage on innovative behavior scores. Each box represents innovative behavior scores' interquartile range (IQR) for distinct experimental conditions. Notably, participants exposed to foresight prompts (SF present) exhibit a visibly higher median innovative behavior score compared to those without foresight prompts (SF absent), i.e., (M = 6.56 vs. M = 5.07), corroborating the earlier descriptive statistics. Furthermore, the impact of AI usage becomes evident as the box plot illustrates a nuanced relationship. Participants with moderate AI use showcase an elevated median (M = 7.70). This aligns with the findings that moderate AI use outperforms both no AI use and high AI use groups, supporting Hypothesis H2b. Conversely, high AI use and no AI use (in the presence of a foresight prompt) constrain innovative behavior, evidenced by a comparatively lower median than the one in the moderate AI-use condition (in the presence of a foresight prompt). This nuanced depiction supports Hypothesis H2b.

Research limitations. *There are also limitations of the study. The sample size, consisting of participants with similar backgrounds, might not represent the broader organizational population, restricting the generalizability of the findings. Similarly, the controlled laboratory setting, though providing standardized conditions, may reflect something other than real-world organizational intricacies. However, despite some scholars' skepticism toward the realism of experiments, they are strongly "useful for zooming in on one particular part of a process and studying how it works" (Derbyshire et al., 2023, p. 9). This is what we aimed for and did via the investigation of the use of AI during strategic foresight toward innovative behavior. An experiment conducted on participants in a real company undertaking that strategic foresight exercise, then conceptually replicated across several other companies, adds solidity to the unveiled results.*

Additionally, using ChatGPT introduces its own set of constraints. Despite its vast capabilities, its performance can be contingent on the nature of the task, or any potential biases present in the training data. Viewing our results in the context of this specific AI tool becomes essential. The evaluation criteria, which depended on expert evaluations for *innovative behavior, might miss the broader spectrum of behaviors or their actual impact on market success. The study's emphasis on a specific consumer product from a crowdfunding platform also narrows its applicability to other industries. Incentive structures, such as gift vouchers and competitive elements, might influence participant responses and behaviors, possibly altering the results. Such demand characteristics need due consideration when interpreting the findings.*

Managerial implications. *The findings of this study have implications for both managerial practice and organizational strategies aimed at fostering strategic foresight and innovative behavior. In this vein, managers play a pivotal role: embracing strategic foresight as a strategic compass enables them to envision the future landscape of their organizations.*

Therefore, to foster strategic foresight, managers and organizations must establish conditions for two key aspects: 1) enabling managers to engage in multi-level thinking in foresight, and 2) effectively managing AI assistance in foresight. In addressing the first aspect, actionable implications for practice emerge. A primary focus should be on training managers to comprehensively evaluate the company and its future development factors, urging them to embrace multi-level thinking in foresight. This involves expanding their perspective on product innovation to encompass organizational, strategic, and operational processes and internal and external environmental considerations.

To achieve a balanced and effective integration of AI in strategic foresight, organizations should establish a comprehensive framework that outlines the strategic deployment of AI alongside human intelligence. Clear guidelines and policies for moderate AI use must be developed, defining thresholds and scenarios where AI can enhance decision-making without leading to information overload or over-reliance. Cross-disciplinary collaboration is crucial, encouraging communication and decision-making among interdisciplinary teams comprising data scientists, AI specialists, as well as people who understand how individual and organizational behavior works. Continuous monitoring and evaluation mechanisms should be implemented to assess the impact of AI applications in foresight, enabling organizations to adjust usage based on performance and feedback (Keding and Meissner, 2021). Training programs for AI literacy are essential, ensuring that decision-makers and foresight practitioners understand the capabilities and limitations of AI for informed and responsible usage. Finally, involving key stakeholders in the decision-making process regarding AI use fosters a comprehensive and inclusive approach.

Originality of the paper. *We examined links between foresight and innovative behavior and the impact of AI usage on it. The findings of the 2x3 factorial design confirmed the formulated hypotheses. First, strategic foresight positively affects innovative behavior. Second, while too much or too little AI use can negatively influence this relationship, a moderate amount appears to be just right, acting positively.*

Keywords: *Strategic foresight; Artificial Intelligence; Innovation; Innovative behavior; ChatGPT*

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A Systematic Literature Review on AI-empowered Strategic Decision-Making process

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Abstract

The purpose of this paper is to create a more comprehensive understanding of how artificial intelligence is revolutionising the way strategic decisions are made. Indeed, despite the massive use of AI in business contexts, especially to perform operational and tactical tasks, its potential at a more strategic level still requires further investigation. Using a systematic literature review based on 42 papers drawn from Web of Science and Scopus, we identify 3 macro-thematic areas - (1) antecedents and Risks of AI Use in strategic decision-making, (2) outcome orientation, (3) process orientation - as well as some sub-themes in the second and third categories. We conclude by providing some insights on future avenues of research.

Keywords*: strategic decision making, artificial intelligence, decision; outcomes, process*

Framing of the research. *Effective decision-making is a crucial factor contributing to organizational success (Blenko et al., 2010). Several literature reviews have been conducted to investigate AI/human collaboration to perform some operational and repetitive tasks such as human resource training, recruitment and performance evaluation (Qamar et al., 2021; Votto et al., 2021; Vrontis et al., 2022) as well as advertising, promotion and pricing activities (Verma et al., 2021; Vlačić et al., 2021), smart manufacturing activities (Cioffi et al., 2020; Wang et al., 2021). These are indeed some of the areas in which AI has spread at an incredible pace in the last decades. However, a big challenge to be explored is whether and how AI can provide significant support to human decision-makers for more complex and impactful strategic decisions.*

Purpose of the paper. *Despite the growing popularity of AI as a topic at the intersection of different research fields - information science, computer science, and management - its implications for management research in decision-making have been predominantly studied by exploring its use at an operational and tactical level (Niu et al., 2021; Rana et al., 2022). The purpose of our paper using a systematic literature review is to examine the adoption of the disruptive technology of Artificial Intelligence (AI) in strategic decision-making.*

Methodology. *Systematic literature reviews provide a rigorous scheme of the activities performed by scholars while conducting a literature review: "assembling, arranging, and assessing existing literature in a review domain (i.e., the 3 As)" producing as an outcome a "state-of-the-art understanding of existing literature and a stimulating agenda to advance understanding through new literature in the review domain (i.e., the 2 Ss)" (Paul et al., 2021, p. 2). A systematic review aims to select and map findings of research papers that meet specific inclusion criteria, consistently with previously defined research questions, applying a replicable and transparent protocol. The adoption of such a scientific method distinguishes systematic reviews from traditional narrative reviews and allows for the reduction of bias during the review process, thus providing robustness to the findings and conclusions drawn by researchers (Snyder, 2019; Tranfield et al., 2003). The output generated is a robust overview of evidence in the research domain of interest (Petticrew & Roberts, 2008). The review has been conducted through the steps detailed in Figure 1 below.*

Findings. *Based on our analysis we grouped our themes into outcome-based, process-based and antecedents-based, evidencing how the literature until now has tried to shed light on the possible positive or negative antecedents of the adoption of AI in strategic decision-making the outcomes resulting from it and some aspects characterising the process itself. In considering each theme also identified the methodologies adopted.*

Antecedents and Risks of AI Usage

Some scholars have investigated drivers and barriers to AI adoption in strategic contexts (Kar et al., 2021). However, the majority of the studies dealing with this topic in our sample do not explicitly refer to strategic-level decisions, but adopt a general perspective on decision-making.

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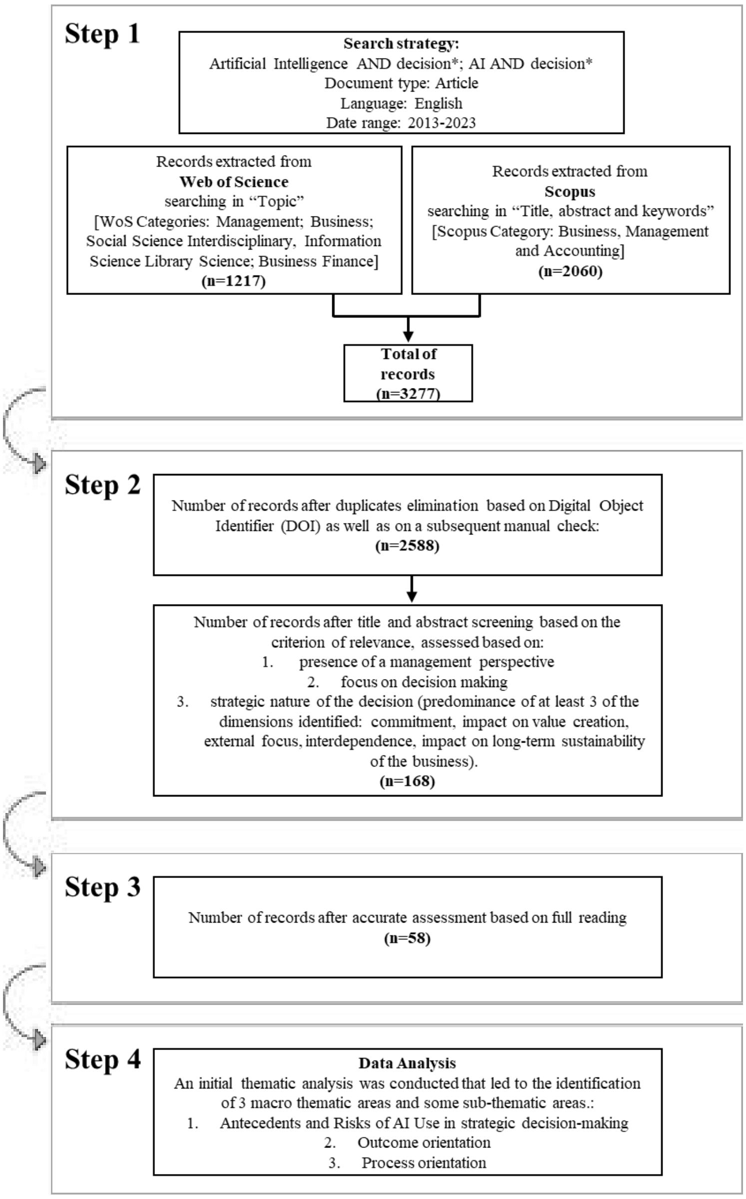
Additionally, some of the studies that mainly deal with outcome and process oriented factors, provide some useful insights on antecedents that have enriched the general understanding of this aspect of the topic.

Some antecedents are linked to human-AI interactions for the integration of AI in organisations (Fares et al., 2022). First of all, what can significantly hinder AI adoption even in strategic contexts is the lack of awareness of the need of AI by decision makers (Chen et al., 2021).

Fig. 1: SLR process



If this barrier does not hold, then the others can be taken into account. The behavioural anomaly of algorithmic aversion as the reluctance of managers to rely on algorithms for their decisions (Mahmud et al., 2023) is undoubtedly a great barrier to AI adoption, especially in strategic contexts (Brink et al., 2023). It can be influenced by what is referred to as the degree of digital/technological readiness (Eriksson et al., 2020; Kondapaka et al., 2023). Other barriers that occur at an individual level are threat to job security (Chen et al., 2021; Kar et al., 2021), perceived risk and reliance on AI, as well as perceived control over AI (Solberg et al., 2022). Ethical concerns on the lack of moral responsibility of AI algorithms for their decisions are also relevant in shaping human attitude (Trunk et al., 2020).

Some however arise at a higher organisational level. Examples are lack of AI talent, lack of AI strategy, lack of infrastructure, challenge in problem selection and lack of leadership commitment (Kar et al., 2021). At an aggregate level, an overarching organisational culture is also considered a relevant factor in influencing the propensity toward AI adoption (Eriksson et al., 2020; Fares et al., 2022). However, even organisational structure and the allocation of resources as well as the overall organisational strategy play a key role in the choice of AI applications for strategic decision-making (Trunk et al., 2020).

There are then some antecedents which have their roots in AI characteristics and functioning as well as in the input data of AI algorithms. Some examples are: state of AI (it may be too narrow-focused and not suitable to the type of *company and its level of maturity); reliability of AI (error tolerance, biases and accuracy); data and privacy concerns (Chen et al., 2021; Jiang et al., 2023; Kondapaka et al., 2023), data leakage, and unpredictable AI behaviours (Jiang et al., 2023), lack of reusable algorithms, lack of usable data (Kar et al., 2021). Data transparency is instead a driver of AI adoption (Trunk et al., 2020).*

Serious risks are represented by over-reliance on intelligence decision-making, and unpredictable AI behaviours (Jiang et al., 2023), risk of inaccuracy due to the training of AI on different datasets, lack of transparency and exposure to hackers' attacks (Pietronudo et al., 2022).

Outcome-orientation

A large body of literature explores the outcomes generated by the implementation of AI to make strategic decisions in different contexts (Anderson, 2019; Kinkel et al., 2023). We identified 4 main subcategories: impact of AI on performance measures and competitive advantage, impact of AI on specific decisions, impact of AI on capabilities and outcome measures, impact of AI on capabilities and/or decision-related constructs.

Impact of AI on performance measures and competitive advantage

This subgroup includes the investigated impacts of AI on outcome variables linked to firm performance or competitive advantage. For example Behera et al. (2023) investigate how the implementation of Explainable Artificial Intelligence (XAI) solutions by a consumer packaged goods retailer can drive sustainable growth. Abrokwah-Larbi and Awuku-Larbi (2023) use the construct "Artificial Intelligence in marketing" (AIM) - composed of the Internet of Things, Collaborative decision-making systems, virtual and augmented reality and personalisation - and evaluate its impact on small and medium-sized enterprises performance, driven by the ability of AI to process information and eventually generate previously unidentified insights. These insights provide SMEs with superior knowledge, thus guiding and enhancing the quality of their decisions.. Focusing on a B2B context, where customer relationship management (CRM) is considered a strategic activity, Chatterjee et al. (2021) show how the shift from legacy to AI-CRM eventually leads to organisational performance and competitive advantage improvements, because it influences B2B engagements, employee experience and information processing.

The impact on performance can also be considered in a broader sense, investigating the overall increase in the performance of an organisational function (i.e. increase in the performance of the purchasing function (Allal-Chérif et al., 2021)).

Impact of AI on specific decisions

The most common fields of study in this group are marketing and investment decisions. We found that some studies explore the role played by AI in the process that leads to location decisions, concerning both production processes and headquarters. Kinkel et al. (2023) in a cross-country research in the manufacturing industry found that AI use - operationalised with an AI use index measured in terms of big data analysis, business processes planning and optimisation, and autonomous decision-making processes - is a determinant for relocation decisions of production activities (offshoring or backshoring strategies). Additionally, they document a significant positive moderating effect of digital competencies and a negative moderating effect of international ambidexterity only in the relationship between AI use and backshoring decisions. The results are explained by the fact that exploiting data and automating some decisions can enable firms to enhance control over global network activities, thus facilitating and encouraging offshoring as a suitable production location strategy. An experimental design is instead adopted by Anderson (2019) to compare the predictive power of different decision models, one of which - the modern approach - entails the use of artificial intelligence. The decision outcomes in this context concern the selection of cities for Amazon Inc. to locate its headquarters 2.

Other studies were conducted by applying and testing artificial intelligence algorithms to assess their performance in making specific decisions. For example, Khosrowabadi et al. (2022) conducted a study in the field of judgemental forecasting by applying a random forest machine learning algorithm. Blohm et al. (2022) investigate the support provided by machine learning algorithms in early-stage investment decisions made by business angels, by applying a gradient-boosted decision trees algorithm and providing evidence that the hypothetical performance of the algorithms is higher than the performance of business angels' decisions in terms of returns. Eventually, as evidenced by Keding and Meissner (2021), the integration of AI systems strongly influences R&D decisions, and the decision-maker perceives that it increases the quality of the decision itself.

Impact of AI on capabilities and outcome measures

Some studies in this stream leverage the idea that AI can contribute to the creation or strengthening of specific capabilities. In a large portion of studies, the capabilities analysed are some of those which in turn drive performance improvements and competitive advantage or influence a specific decision. Mikalef et al. (2023) explore the mechanism through which AI competencies influence B2B marketing capabilities (Information Management, Planning and Implementation), and in turn firm performance. In the same vein, Chen and Lin (2021) conceptualise and test a model to show how the three capabilities that compose Business Intelligence - namely sensing, transforming and driving capability (all empowered by AI solutions) - in addition to exerting an influence among each other, eventually affect firm performance. Consistently, drawing on Knowledge Management Theory, Bag et al. (2021), incorporate in their model three variables that operationalise the capability to create knowledge on the customer, user and external market, and a *decision-related variable (marketing rational decision-making). Their results confirm that knowledge creation is enhanced by Big Data powered Artificial Intelligence and positively affects decision-making, which eventually impacts performance.*

The integration of AI in the business intelligence infrastructure also leads to improved performance appraisal capabilities, which affects competitive advantage (Wang et al., 2022). Polas and Raju (2021) account for the contribution of AI in enhancing the entrepreneurial capabilities of a firm concerning opportunity recognition, development and exploitation, thus indirectly influencing its entrepreneurial marketing decisions. Under a similar perspective, Kumar et al. (2023) investigate the effect of AI-enabled CRM capability on innovative performance measured in terms of service innovation. In all these studies, AI plays a crucial role in transforming information into usable knowledge to inform marketing decisions at all levels, including strategic ones such as product or process innovation. In the innovation field, the role played in reaching a final innovation decision also takes into account its contribution to some intermediate outcomes in terms of innovation capabilities (Recker et al., 2023).

In their conceptual framework, Chen et al. (2021) highlight the support provided by AI adoption to learning capabilities and then to some measures of financial, relational (in the B2B marketing context) and innovation outcomes.

Other decision-related capabilities that can be reinforced by AI are rationality, creativity, knowledge creation capability and absorptive capacity, as well as collective intelligence, but also the capability to innovate the decision-making process itself (Pietronudo et al., 2022).

Impact of AI on capabilities and/or decision-related constructs

Some contributions explicitly account for the role of a decision-related variable (alone or in addition to a capability-related variable) in influencing performance. These constructs generally express a measure of decision-making performance in terms of accuracy, precision, reliability, time and effort (Speier et al., 2003). Rahman et al. (2022) test and confirm the hypothesis that marketing analytics capability - the ability to gather, organise, and examine data to obtain valuable insights for marketing decisions - is positively related to competitive marketing performance. This relationship is mediated through holistic marketing decision-making and strengthened by the adoption of AI, which also positively moderates the connection between marketing analytics capability and holistic marketing decision-making. In this stream, Krakowski et al. (2023) find that the substitution of human cognitive capabilities, which are considered strategic to gain competitive advantage, with a widely accessible resource such as AI, would eventually erode competitive advantage, and this is consistent with the RBV theoretical framework. However, the combination of human cognitive capabilities referred to previously unrelated domains and machine computational capabilities generates new and enduring advantages. Therefore, according to these findings, the evaluation of the role of AI in enhancing competitive performance should take into account the degree of support provided to human decision-makers. AI is considered to generate a general improvement in decision making efficiency and accuracy while also reducing risk and costs of incorrect decisions (Chen et al., 2021).

However, not only does AI boost human decision makers' analytical capabilities, but it also supports their creativity and is becoming increasingly good at performing tasks that require tacit judgment or emotions sensing (Duan et al., 2019).

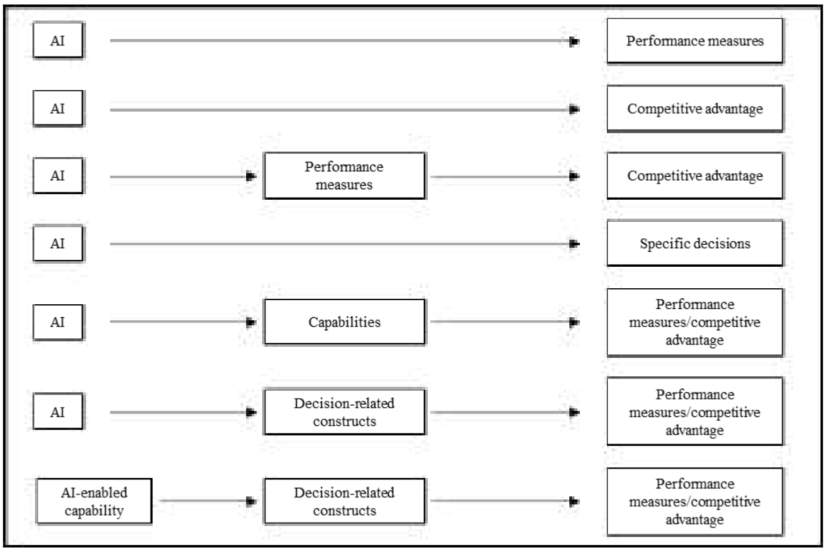
Process Orientation

Based on our analysis we identified a theme that focused on the decision-making process rather than its outcome. The

Delegation

A large and varied body of literature explores the facets of human-machine collaboration within the decision-making process. The first aspect to be highlighted in this field is delegation, the mechanisms through which the collaboration itself can take place. Schneider and Leyer (2019) investigate the willingness of managers to delegate strategic decisions to algorithms depending on the decision complexity and situational awareness of the decision-maker. They find that the degree of complexity does not actually influence the likelihood of delegating, while low levels of situational awareness significantly lead to a higher likelihood of delegating the decision to an algorithm. According to Fügener et al. (2022), delegation may occur in both directions: humans to algorithms and vice versa. Indeed, humans are endowed with hidden knowledge that does not fully manifest itself in human behaviour and, therefore, cannot be "taught" to machines but, conversely, machines have a great potential in discovering solutions that go beyond human processing capacity. The combined performance resulting from the collaboration between the two actors should be higher than the performance of the best-performing actor, but it depends on the ability to properly exploit the delegation mechanism: humans are less likely to delegate effectively due to the lack of sufficient metaknowledge; on the contrary, AI is effective in delegating to humans. The collaboration based on delegation may take different forms: hybrid (human-to-AI and AI-to-human) sequential decision-making and aggregated human-AI decision-making (Shrestha et al., 2019).

Fig. 2: Overview of outcome-based findings



The delegation issue may become even more complicated in big corporations endowed with analytics centres of specialised data scientists. In such contexts characterised by information asymmetry between the data scientist and senior managers responsible for making the decisions based on analytical results, a principal-agent problem arise, which can be mitigated by setting clear shared objectives (Willigers, 2020).

subcategories in this theme are: delegation, Complementarity of knowledge and skills, intuition and bias.

Complementarity of knowledge and skills

Other studies instead aimed at unveiling how human-machine collaboration occurs in terms of skills and cognitive abilities complementarity.

Although Arnott et al. (2017) claim that there is limited room for a strong interaction between human cognitive abilities and the set of rules and algorithms that can inform decisions in the field of strategic planning, other scholars have attempted to shed light on the relationship between the two actors in a strategic decision-making context. In this stream of literature, a fundamental aspect brought up to the discussion is the different knowledge they can exploit. Explicit knowledge, codified and stored, is the easiest to be transferred to and processed by AI systems. Tacit knowledge is instead rooted in experience and this characteristic prevents the possibility to train AI algorithms with it (Kondapaka et al., 2023). However, the tacit knowledge possessed by individuals is thought to make the difference when it comes to strategic decisions, which Metcalf et al. (2019) refer to as known unknown. As emerges from the study by Kondapaka et al. (2023), along with tacit knowledge, in a strategic context there are some human characteristics that are hard to imitate by AI and therefore define the role of the human decision-maker: experience, creativity, judgment, wisdom. On the other hand, the role played by AI is justified by its ability to extract patterns from data and may consist of supporting, assisting, reviewing, consulting, inspiring or helping. According to their findings, the harmonisation of the two roles can be reached by connecting the two actors effectively and by reaching the right balance between explicit and tacit knowledge. Therefore, as pointed out by Eriksson et al. (2020), the role played by AI in strategic decision is mainly linked to its rational abilities: it identifies, processes and reviews relevant information that will eventually influence the decision. However, they also argue that AI can make the decision, with the manager acting as a supervisor.

In line with the idea of reaching a harmonious level of collaboration between the two actors, the achievement of a higher-level intelligence can also occur thanks to the implementation of a particular type of AI solution, the so-called artificial swarm intelligence (ASI). This is relevant when dealing with known unknown strategic decisions since it allows groups of highly competent individuals to work and collaborate as a unique "supermind" (Metcalf et al., 2019). The computational power of AI in such applications is exploited not just to extract insights from data (e.g. machine learning algorithms), but to realise a powerful collaboration between individuals that can provide a valuable contribution to the decision, thus leveraging both explicit and tacit knowledge.

A different perspective on knowledge and skills interaction is offered by the idea that AI augments human tacit knowledge by supporting humans' learning processes. This has been tested by Gaessler and Piezunka (2023) in a difference-in-difference framework based on two computer chess natural experiments. The interactions occurring in such an experiential learning context, despite being far from real-life strategic situations, are thought to be useful examples of complex strategic interactions where the potential of AI in supporting human learning can be tested. The results of these AI-backed computer simulations show that players who trained with AI are more likely to win. According to Trunk et al. (2020), there is a clear division of tasks between humans and AI such that the definition of goals can only be performed by humans, AI can outperform humans in collecting information, but the role of humans remail crucial in identifying the relevant sources and in contributing with the non-codified knowledge they own. Then human may equal or outperform AI in interpretation tasks. In the definition of alternatives, assignment of utilities and probabilities and weighting and *decision tasks, AI support turns out to be precious in performing the mathematical calculations, which are, however, based on rules predefined by humans and will always have to be evaluated by humans.*

Intuition

In analysing the human-machine interplay, a key aspect pointed out by various scholars, especially in conceptual papers, is intuition, to which humans generally resort for complex decisions (Simon, 1957). Indeed, AI can contribute to both rational and intuitive decision-making, which characterises many strategic contexts. The support provided to the former is due to its computational power that allows it to analyse historical data as well as identify and compare different courses of action. However, surprisingly, it can also support the latter. It is undeniable that the reliance on intuitive decision-making on past experiences and feelings that cannot be taught to AI as well as the lack of data on similar situations that occurred in the past, both prevent AI from providing useful guidelines to make intuitive decisions. However, it is anyway thought that AI indirectly contributes to the creation of tacit knowledge that feeds the cognitive structures of managers by means of the insights provided in those situations where historical data are available and that eventually feed managers' intuition (Tabesh, 2022). Human-machine collaboration in decision-making can be seen as a partnership built on a strict division of work, based on the advantages of each of the two partners. In decision-making situations characterised by uncertainty, complexity, and equivocality, none of the two actors would be sufficient alone. In facing uncertainty, humans contribute by means of their intuition to face the unknown and AI provides access to useful real-time information. Confronting complexity, humans identify the necessary data and the sources, AI is responsible for collecting and processing it and humans, again, will be able to select the best course of action among alternatives equally supported by data. Eventually, in dealing with equivocality, AI contribution consists of analysing sentiments and providing possible interpretations while the human role mainly implies negotiation and the tentative to build consensus. However, humans are considered to have a superior performance in such situations due to their ability to consider the big picture and evaluate some qualitative contextual aspects such as political and social situations (Jarrahi, 2018). According to Vincent (2021), the key to an effective collaboration between human intuition and AI lies in two factors: a high level of expertise of the decision maker and the ill-structured nature of the decision.

Bias

Another aspect that influences human-machine performance and their interplay in the decision-making process and that deserves even more attention at a strategic level is represented by bias. Not only humans but also machines are affected by biases in their predictions and decisions. Edwards and Rodriguez (2019) clarify how six relevant types of bias typically associated with humans can indeed affect both machines that perform analytics and humans in relating to it at the different stages of the analytics process (acquisition, information extraction, data integration, analytics and interpretation). They are referred to as bias towards the first information received, keeping the status quo, justifying past choices, supporting instinct, problem-solving methods affecting decisions, and lacking forecast feedback. The authors also propose some strategies to overcome them. Similarly, Van Giffen et al. (2022) highlight some biases affecting machines in the different data mining phases and suggest mitigation strategies: social bias, measurement bias, representation bias, label bias, algorithmic bias, evaluation bias, deployment bias, and feedback bias. Their resolution always requires human intervention. Conversely, some behavioural biases affecting human decision-makers can be circumvented by means of algorithms (Hasan et al., 2022). These biases may lead to suboptimal decisions (Brintrup et al., 2023).

Research limitations. *The study has some limitations. Findings are limited to the databases of WoS and Scopus and are affected by our choice of keywords as well as by the manual selection of the final sample of contributions. Second, other AI-related terms may be considered for future developments. Eventually, no primary data was used to support our research agenda. Furthermore, since the focus of the study is represented by strategic decisions, which may concern several different topics and entail the involvement of various organisational functions, our findings rely to some extent on context-specific information, whose generalisability needs to be further tested in future research. However, this was a necessary compromise, in the attempt to create a high-level overarching understanding of AI in strategic decision making.*

Managerial implications. *The work has significant managerial implications. It provides insights for a deeper understanding of the AI-empowerment of strategic decision making, which is a crucial process for firms' success and growth. In particular, it can contribute to enhance manager's awareness on the possible short and long term effects of integrating AI in this process as well as on the way it can be exploited to create real synergies. AI can indeed enable to fully take advantage of the data available for the creation of both explicit and tacit knowledge, for strategic scenarios' creation and enhanced predictions.*

Originality of the paper. *Despite the rapid growth in AI research, literature on AI with a focus on strategic decision making is still fragmented. Our study aims to fill this gap, contributing to extant literature on strategic decision making by providing an overview of the changes in the field resulting from the adoption of a AI solutions.*

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Gen-AI nel settore agri-food: determinanti d'adozione ed impatto organizzativo

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Abstract

Lo sviluppo della Gen-AI sta progressivamente trasformando le modalità di produzione e distribuzione dei prodotti agroalimentari, consentendo agli operatori del settore di definire strategie più mirate, ottimizzare i processi e migliorare la produttività. Ciò in quanto, gli algoritmi di intelligenza artificiale generativa possono identificare modelli e tendenze che consentono agli agricoltori di prendere decisioni più strategiche e tempestive per massimizzare i rendimenti delle colture e minimizzare gli sprechi, nonché agli operatori logistici di migliorare l'efficienza della catena di approvvigionamento ottimizzando i processi, la gestione degli stock e la distribuzione. Sebbene ormai diverse sono le applicazioni Gen-AI nel settore agri-food, ancora limitati sono i contributi in letteratura che indagano gli effetti della Gen-AI in questo ambito. Ciò evidenzia la necessità di sviluppare ulteriori studi al fine di analizzare il potenziale trasformativo e le sottili ramificazioni dell'integrazione della Gen-AI all'interno dei paradigmi produttivi del settore agrifood. In questo contesto, la presente ricerca si propone di discernere le molteplici determinanti che impattano l'adozione della tecnologia Gen-AI nei contesti agroalimentari, le quali includono dimensioni tecnologiche, ambientali e organizzative. Lo studio, invero, si propone di analizzare i fattori che influenzano l'intenzione di adozione della Gen-AI tra gli operatori del settore agri-food e, al contempo, l'impatto della struttura organizzativa e del top management sugli stessi. La ricerca, oltre ad implementare la letteratura sulla tecnologia Gen-AI, fornisce evidenze empiriche che illuminano aspetti poco noti dell'intersezione tra Gen-AI e agri-food, presentando implicazioni teoriche e manageriali significative.

Key words: *Gen-AI, agri-food, technologies, IA, digital transformation*

Inquadramento della ricerca. *L'adozione delle tecnologie nel settore agroalimentare rappresenta una rivoluzione che sta modificando in modo significativo l'agricoltura, dalla produzione alla distribuzione, in risposta alle sfide globali quali la crescita demografica, il cambiamento climatico e la scarsità di risorse naturali, con l'obiettivo di garantire la sicurezza alimentare (Guerrero et al., 2023). L'integrazione delle tecnologie nel settore agroalimentare è fondamentale per affrontare le sfide contemporanee, migliorando la produttività e la sostenibilità dell'agricoltura (Gebresenbet et al, 2023). Questi avanzamenti tecnologici richiedono un approccio olistico che consideri aspetti economici, sociali ed etici per garantire un impatto positivo a lungo termine sul settore e sulla società nel suo insieme (Quattrociocchi et al, 2022). L'agricoltura di precisione, in particolare, sfrutta dati e tecnologie avanzate come GPS, droni (Quattrociocchi et al. 2022), sensori in campo (Saha et a.l, 2023) e sistemi di irrigazione intelligenti per ottimizzare l'utilizzo delle risorse e massimizzare i rendimenti delle colture (Pansoy, et al., 2024). Questi strumenti permettono una gestione agricola mirata, con un minor impiego di acqua, fertilizzanti e pesticidi, contribuendo a ridurre l'impatto ambientale dell'agricoltura (Schrijver et al. 2016).*

In tale contesto la digitalizzazione e l'integrazione dei dati ricoprono viepiù un ruolo rilevante per il progresso nel settore, con piattaforme di gestione agricola basate su cloud e intelligenza artificiale (IA) che migliorano la capacità decisionale degli agricoltori attraverso l'analisi di grandi volumi di dati in tempo reale. L'IA, in particolare, emerge come strumento essenziale per prevedere le tendenze di mercato, ottimizzare le catene di approvvigionamento e rafforzare le strategie di marketing (Liakos et al., 2018; Kamilaris et al., 2019).

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L'IA, infatti, trova applicazioni sempre più estese in agricoltura, promuovendo l'efficienza operativa e riducendo la necessità di manodopera (Huang et al., 2018). Tuttavia, l'adozione di tecnologie avanzate pone sfide, come l'alto costo e l'accessibilità per i piccoli produttori, la necessità di competenze tecniche e preoccupazioni legate alla sicurezza dei dati (OECD, 2019). L'IA facilita decisioni più consapevoli e una gestione efficiente nella produzione e distribuzione alimentare, promuovendo la sostenibilità e la sicurezza alimentare (Ravikumar, A., 2022).Tra le diverse tipologie di IA si distingue la Generative Artificial Intelligence (Gen-AI). La Gen-AI si riferisce a quelle tecnologie IA che possono generare nuovi contenuti, dati o simulazioni che non esistevano prima, apprendendo da vasti dataset esistenti (Nasirahmadi & Hensel 2022). Nel settore agri-food, ciò può tradursi in una serie di applicazioni, dalla progettazione di colture geneticamente modificate per resistere a condizioni climatiche avverse, alla creazione di diete personalizzate per il bestiame che ottimizzano la loro crescita e benessere (Garcia 2023).

La Gen-AI può essere utilizzata in vari ambiti del settore agrifood; a titolo esemplificativo, questa consente l'uso di modelli predittivi per ottimizzare i rendimenti delle colture. Attraverso l'analisi di dati raccolti da sensori in campo, immagini satellitari e modelli climatici, gli algoritmi di AI possono prevedere con precisione i risultati delle colture, consentendo agli agricoltori di prendere decisioni informate su quando piantare, irrigare e raccogliere. In taol senso Liakos et al. (2018) hanno esplorato l'uso di tecniche di machine learning per prevedere i rendimenti delle colture, dimostrando l'efficacia di questi strumenti nel migliorare la produttività agricola.

Un altro ambito di applicazione della Gen-AI è nella genetica delle colture e nell'ingegneria genetica, dove può accelerare la creazione di varietà di piante in grado di resistere a parassiti, malattie e stress ambientali. La ricerca in questo settore sta esplorando come gli algoritmi di AI possono analizzare sequenze genetiche per prevedere quali modifiche porteranno ai tratti desiderati, riducendo significativamente il tempo e i costi associati allo sviluppo di nuove varietà. Hickey et al. (2019) illustrano come la Gen-AI possa essere utilizzata per simulare l'effetto di modifiche genetiche, facilitando la selezione delle colture ottimali.

Inoltre, la Gen-AI trova applicazione nel miglioramento della sicurezza alimentare e nella tracciabilità della catena di approvvigionamento. Attraverso l'utilizzo di sistemi AI che possono generare e analizzare dati in tempo reale, è possibile monitorare la provenienza del cibo, le condizioni di stoccaggio e trasporto, garantendo la qualità e riducendo il rischio di contaminazione. Recenti studi (Ambika 2023; Pedro M., et al., 2023) evidenziano come le tecnologie blockchain e AI possano collaborare per creare sistemi di tracciabilità alimentare affidabili e trasparenti.

La Gen-AI permette, inoltre, di creare prodotti alimentari personalizzati in base alle preferenze nutrizionali e ai bisogni specifici dei consumatori. Utilizzando algoritmi di apprendimento automatico, è possibile sviluppare ricette su misura che tengano conto di allergie, intolleranze, obiettivi nutrizionali e preferenze di gusto (Ramakrishnan et al, 2023).

AgriGPT, ideato da un agricoltore francese tecnofilo, è un esempio di applicazione di AI generativa in agricoltura. Questa AI offre consulenze agricole personalizzate combinando dati agricoli, informazioni in tempo reale e un sistema di feedback utente attraverso un'interfaccia multi-modulare. Allenato su ampi set di dati che includono condizioni del suolo, climatiche e strategie contro i parassiti, inoltre fornisce consigli per migliorare la resa dei raccolti (Liu et al. 2023). Beneficiando delle funzionalità di ChatGPT, migliora anche la documentazione, la reportistica e il processo decisionale, contribuendo significativamente all'efficienza e produttività nel settore agricolo e promuovendo la sostenibilità.

Un settore emergente che beneficia della Gen-AI è lo sviluppo di alimenti alternativi, come le proteine vegetali e la carne coltivata in laboratorio (Liu et al, 2023). La capacità di simulare e ottimizzare processi biologici e chimici tramite algoritmi AI consente di esplorare nuove formulazioni alimentari che possono ridurre la dipendenza da agricoltura intensiva e allevamento, contribuendo alla sostenibilità ambientale. Da un punto di vista della supply chain management, la Gen-AI trova impiego nel migliorare la tracciabilità e l'efficienza della catena di approvvigionamento alimentare, algoritmi predittivi possono prevedere la domanda di prodotti agricoli, ottimizzare la logistica del trasporto e ridurre gli sprechi alimentari, contribuendo a una maggiore sostenibilità (Onyeaka et al., 2023).

Nonostante le premesse, l'applicazione della Gen-AI nel settore agri-food presenta diverse sfide, tra cui questioni etiche legate alla manipolazione genetica, l'accesso e l'interpretazione dei dati nonché la necessità di infrastrutture tecnologiche avanzate. È fondamentale che l'adozione di queste tecnologie proceda con una considerazione attenta delle implicazioni sociali, economiche ed ambientali, come sottolineato in studi che esaminano l'impatto dell'AI sull'agricoltura sostenibile e la sicurezza alimentare (Bronson & Knezevic, 2016).

Obiettivo dell'articolo. *Il presente studio si propone di indagare i fattori che determinano l'adozione della Gen-AI, ponendo attenzione a come determinate variabili influenzano la propensione all'adozione di tale tecnologia, pertanto, lo studio muove dalle seguenti domande di ricerca:*

***RQ1**: Quali sono i fattori che influenzano l'intenzione di adozione della Gen-AI tra gli operatori del settore agri-food?*

***RQ2**: Il Management aziendale influenza l'adozione della tecnologia Gen-AI nel settore agri-food?*

Attraverso l'applicazione di quadri teorici consolidati relativi all'adozione tecnologica, si persegue una valutazione olistica che considera le diverse variabili in gioco e il loro impatto sulle tendenze di adozione della Gen-AI nel settore agri-food. Lo studio intende ampliare la conoscenza circa le complesse dinamiche che influenzano l'adozione della Gen-AI nel settore agri-food, arricchendo così il dibattito teorico e offrendo spunti significativi in termini manageriali.

Metodologia. *Nei seguenti paragrafi, discuteremo la metodologia di raccolta dati, il questionario somministrato e le tecniche di analisi dati analitiche.*

Procedura di campionamento

La metodologia adottata in questo studio si avvale di un approccio quantitativo per l'analisi dei dati, focalizzandosi sull'elaborazione di informazioni numeriche ottenute attraverso l'impiego di questionari. La procedura metodologica si articola in due fasi principali. Inizialmente, la raccolta dati è stata effettuata mediante un questionario diffuso tramite la piattaforma online Qualtrics XM, nel lasso temporale esteso da novembre 2023 a febbraio 2024. Questa fase ha previsto l'invio di questionari ai dipendenti amministrativi operanti nel settore agroalimentare, registrando una partecipazione di 156 individui. Successivamente, nella seconda fase dell'indagine, l'analisi dei dati raccolti è stata condotta utilizzando il software statistico SPSS. È rilevante notare che, a seguito della progettazione del questionario che prevedeva la compilazione obbligatoria di tutte le domande, il dataset risultante non presenta valori mancanti.

Struttura questionario

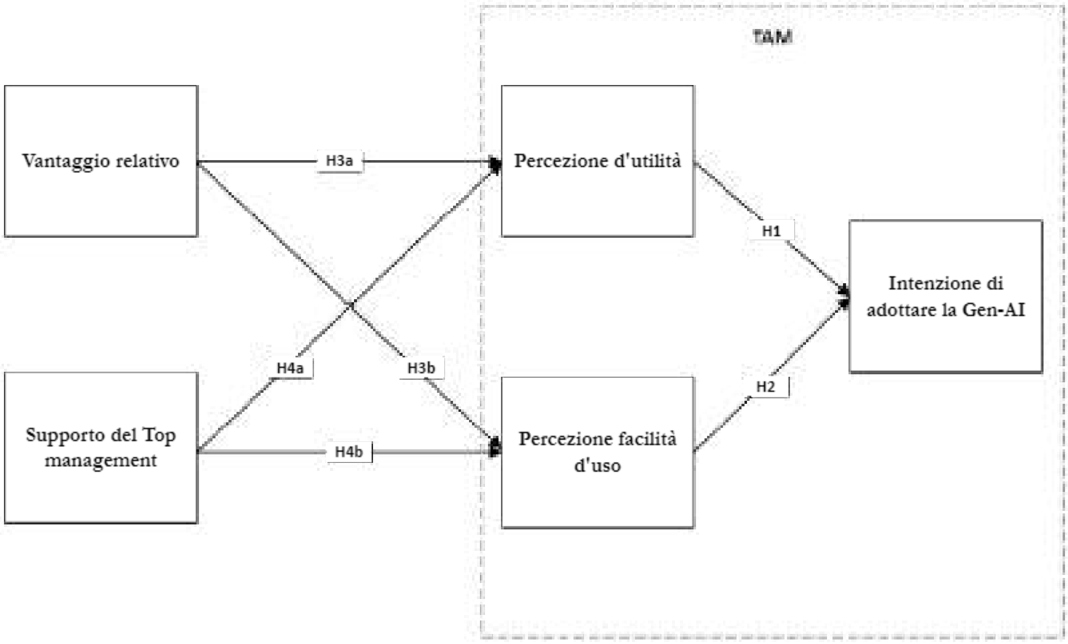
La presente ricerca indaga l'intenzione di adozione delle tecnologie di Intelligenza Generativa Artificiale (Gen-AI) nel dominio agroalimentare, avvalendosi del quadro teorico fornito dal Modello di Accettazione della Tecnologia (Technology Acceptance Model, TAM) come delineato da Davis nel 1989. Il presupposto fondamentale di questa indagine è che l'innovazione tecnologica possieda un vantaggio relativo, come teorizzato da Rogers nel 1983, implicando che le innovazioni sono percepite come superiori rispetto alle precedenti soluzioni. Questo concetto di vantaggio relativo è stato efficacemente incorporato nel TAM e in studi successivi con l'obiettivo di analizzare come le percezioni di miglioramento e beneficio possano influenzare significativamente l'accettazione e l'adozione di nuove tecnologie da parte degli utenti.

In questo contesto, emerge come fattore cruciale il coinvolgimento del "Top management" nel facilitare o ostacolare l'adozione di nuove tecnologie (Barham et al.,2020). In letteratura è stato ampiamente evidenziato l'essenziale ruolo del "top management" nel facilitare il processo di adozione tecnologica nelle organizzazioni. Questa riconoscenza enfatizza come i dirigenti di alto livello siano pivotali non solo nel delineare la visione e la strategia aziendale ma anche nel fornire il supporto necessario o, al contrario, nell'agire come forza di inibizione verso l'innovazione tecnologica (Kumari & Singh,2022). Al-Khatib (2023) sottolinea specificamente che l'efficacia con cui il top management naviga queste responsabilità può significativamente influenzare la capacità di un'organizzazione di abbracciare nuove tecnologie, sottolineando la loro influenza critica sull'esito dell'adozione tecnologica. Questo approccio olistico enfatizza l'importanza di considerare gli aspetti organizzativi e manageriali nell'analisi dell'accettazione tecnologica, contribuendo così a una comprensione più profonda del fenomeno. La rilevazione delle percezioni è stata effettuata attraverso un questionario strutturato su una scala Likert a cinque punti, variando da 1 ("Fortemente in disaccordo") a 5 ("Fortemente d'accordo"). Il questionario prevedeva un'introduzione dedicata alle tecnologie Gen-AI, sollecitando i partecipanti a riflettere su eventuali esperienze pregresse con tecnologie similari. Nell'ambito della nostra analisi, sono stati esaminati diversi costrutti. Il vantaggio relativo, considerato il precursore nel nostro studio, è stato valutato attraverso tre item specifici, mirando a sondare la percezione di superiorità ed efficacia della nuova tecnologia rispetto a soluzioni precedenti, in linea con quanto riportato da Sharma et al. (2022). In aggiunta, tre ulteriori costrutti derivati dal modello TAM-la percezione dell'utilità, la facilità d'uso percepita (Ma X. & Huo Y., 2023), e l'intenzione di adottare la Gen-AI (Chatterjee et al., 2021) sono stati inclusi per un'analisi comprensiva dell'accettazione tecnologica nel contesto agroalimentare. Per quanto riguarda la tecnica di analisi,la presente ricerca adotta metodologie avanzate di regressione lineare multipla per esaminare sia gli effetti diretti che quelli indiretti delle variabili indipendenti sulla variabile dipendente. L'elaborazione e l'analisi dei dati sono state condotte impiegando il software statistico SPSS. Prima di procedere con la verifica delle ipotesi di ricerca, i dati sono stati sottoposti a rigorosi test di validità e affidabilità, utilizzando le Correlazioni di Pearson per la validità e il Coefficiente Alpha di Cronbach per l'affidabilità. Per la formulazione del modello teorico, si delineano le ipotesi che fungono da pilastri per l'analisi e l'interpretazione dei comportamenti di accettazione tecnologica degli utenti.

***H1**: La percezione di utilità influenza positivamente l'intenzione di adozione (Ma X. & Huo Y., 2023)*
***H2**: La percezione di facilità d'uso influenza positivamente l'intenzione di adozione (Ma X. & Huo Y., 2023)*
***H3a**: Il vantaggio relativo influenza positivamente la percezione di utilità (Al-Kathib, 2023)*
***H3b**: Il vantaggio relativo influenza positivamente la percezione di facilità d'uso (Al-Kathib, 2023)*
***H4a**: Il supporto dei dirigenti influenza positivamente la percezione di utilità (Al-Kathib, 2023)*
***H4b**: Il supporto dei dirigenti influenza positivamente la percezione di facilità d'uso (Al-Kathib, 2023)*

La seguente immagine rappresenta le ipotesi attraverso le quali è stato sviluppato il modello.

Fig. 1: Modello teorico dell'intenzione comportamentale



Fonte: Elaborazione propria

Risultati. *L'analisi empirica si caratterizza per la solidità statistica dei risultati ottenuti, in quanto risultano confermate l'adeguatezza e l'accuratezza del framework teorico impiegato. Il nostro studio evidenzia che l'intenzione di implementare la Gen-AI nel settore agri-food è positivamente correlata ai costrutti del TAM e, in modo indiretto dal Vantaggio relativo (RA). Tuttavia, emerge un'eccezione significativa riguardante l'influenza negativa esercitata dal supporto del Top management (TMS) sull'intenzione di adozione di questa nuova tecnologia, contrastando le aspettative iniziali. Si evidenzia, in particolare, l'importanza della Percezione di Utilità (PU) e della Percezione di Facilità d'Uso (PEOU) secondo il TAM, oltre al Vantaggio Relativo, come fattori critici che influenzano positivamente l'intenzione di implementare la Gen-AI nel settore agri-food. L'imprevisto impatto negativo derivante dal supporto del Top Management pone interrogativi di rilievo che aprono ad ulteriori analisi. Risulta significativo che due delle sei ipotesi testate non abbiano trovato conferma empirica, evidenziando un'influenza contraria rispetto all'intenzione di integrare la Gen-AI nel settore in esame.*

Tab. 1: Analisi fattoriale confermativa per il modello di misurazione

Area	Costrutto	Cronbach's Alpha	AVE	CR	Item	Factor Loadings
	Vantaggio relativo	0,858	0,783	0,915	RA1: La tecnologia GEN-AI migliora le prestazioni lavorative in modi migliori rispetto ad altre tecnologie	0,884
					RA2: La tecnologia GEN-AI aumenta la qualità lavorativa di più rispetto ad altre tecnologie	0,819
					RA3: La tecnologia GEN-AI consentirà di risparmiare sui costi.	0,947
TAM	**Percezione utilità**	0,866	0,793	0,920	PU1: L'uso della tecnologia GEN-AI è utile nel mio lavoro	0,934
					PU2: L'uso della tecnologia GEN-AI mi aiuterebbe a realizzare le cose più rapidamente.	0,873
					PU3: L'uso della tecnologia GEN-AI ha aumentato la mia produttività.	0,863
	Percezione facilità d'uso	0,967	0,940	0,979	PEOU1: Imparare ad usare la tecnologia GEN-AI sarebbe facile per me	0,961
					PEOU2: L'interazione con la tecnologia GEN-AI sarebbe chiara e comprensibile per me.	0,962
					PEOU3: Utilizzare la tecnologia GEN-AI sarebbe facile per me	0,986
	Intenzione di adottare GEN-AI	0,931	0,830	0,951	IAA1: Penso che un sistema di lavoro basato sulla tecnologia GEN-AI sia vantaggioso per la nostra organizzazione	0,906
					IAA2: Sono favorevole a un sistema di lavoro basato sulla tecnologia GEN-AI	0,936
					IAA3: Vorrei sfruttare al massimo il potenziale della tecnologia GEN-AI	0,891
					IAA4: Penso che l'utilizzo della tecnologia GEN-AI migliorerà la produttività della nostra organizzazione	0,911

Tab. 2: Verifica delle ipotesi

HP.	***RELAZIONE***	***DESCRIZIONE***	***Valutazione***
H1	*PU -> IA*	*La percezione di utilità influenza positivamente l'intenzione di adozione*	*Confermata*
H2	*PEOU -> IA*	*La percezione di facilità d'uso influenza positivamente l'intenzione di adozione*	*Confermata*
H3a	*RA - > PU*	*Il vantaggio relativo influenza positivamente la percezione di utilità*	*Confermata*
H3b	*RA - > PEOU*	*Il vantaggio relativo influenza positivamente la percezione di facilità d'uso*	*Confermata*
H5a	*TMS -> PU*	*Il supporto dei dirigenti influenza positivamente la percezione di utilità*	*Non Confermata*
H5b	*TMS -> PEOU*	*Il supporto dei dirigenti influenza positivamente la percezione di facilità d'uso*	*Non Confermata*

Limiti della ricerca. *Il presente studio consta di un primo limite; considerati i costrutti presi in considerazione, l'indagine prevede tempi di realizzazione più estesi e un impiego di risorse maggiori rispetto a studi esclusivamente quantitativi. La comprensione del fenomeno, inoltre, può richiedere di integrare l'analisi quantitativa con interviste qualitative approfondite rivolte a manager, con lo scopo di ottenere una comprensione più sfaccettata dei dati quantitativi raccolti. Pertanto, si contempla l'adozione di un approccio metodologico misto in fasi successive della ricerca. Questa strategia permetterebbe di abbracciare sia l'approccio qualitativo, focalizzato sull'interpretazione e la comprensione profonda dei significati, sia quello quantitativo, orientato verso la raccolta e l'analisi di dati numerici.*

L'impiego congiunto di metodologie qualitative e quantitative mira a rafforzare la validità complessiva dei dati raccolti, consentendo un'esplorazione più ricca e multilivello del fenomeno di studio.

Implicazioni manageriali. *La Gen-AI presenta significative possibilità di utilizzo nel settore agricolo, meritevoli di ulteriore approfondimento. Muovendo dalle ipotesi del modello, la ricerca getta luce sulle dinamiche organizzative e sulle sfide manageriali coinvolte nel favorire una cultura di innovazione e adozione tecnologica all'interno del settore agroalimentare. Nonostante l'evoluzione dei modelli organizzativi in vari settori di produzione, i nostri risultati indicano la necessità di sforzi mirati per coltivare una cultura imprenditoriale che sostenga l'adozione di nuove tecnologie, inclusa l'IA generativa. In particolare, l'analisi empirica condotta rivela che, sebbene le aziende agroalimentari mostrino una preparazione organizzativa, il supporto del Top Management nel settore Agri-food non è completamente orientato verso l'adozione e l'implementazione della Gen-AI, influenzando negativamente e indirettamente la percezione di utilità e di facilità d'uso della tecnologia. Questo sottolinea l'importanza di allineare le priorità organizzative e il supporto della leadership con la necessità di integrare tecnologie innovative per guidare la crescita sostenibile e la competitività all'interno del settore agroalimentare. Inoltre, questo studio sottolinea il ruolo centrale svolto dalla percezione dell'utilità e dalla facilità d'uso nel plasmare le intenzioni di adozione della Gen-AI nel settore agroalimentare. Questi due fattori si sono rivelati per esercitare un'influenza diretta e significativa sull'intenzione di adottare le tecnologie Gen-AI, evidenziando la loro importanza critica nel guidare i comportamenti di adozione tra i diversi stakeholder operanti nel settore Agri-food.*

Originalità del paper. *Lo studio si posiziona all'avanguardia della ricerca accademica, indagando un tema relativamente poco esplorato: l'impatto della struttura organizzativa e del coinvolgimento del top management nel processo di adozione della Generative Artificial Intelligence (Gen-AI) nel settore agri-food. La rilevanza del tema è amplificata dalla scarsità di studi pregressi che collegano direttamente l'intelligenza artificiale con le pratiche e le strategie di gestione nel settore agricolo, segnalando un gap significativo nella letteratura esistente. L'originalità del paper è ulteriormente sottolineata dal suo approccio metodologico e teorico, in quanto propone un modello innovativo che integra due fattori critici - il vantaggio relativo e l'engagement del top management - come precursori dell'adozione della Gen-AI nell'agri-food. Questa prospettiva bidimensionale non solo arricchisce il dibattito accademico sull'importanza della tecnologia Gen-AI nel settore agri-food ma apre ulteriori nuovi orizzonti idonei a comprendere come le dinamiche interne alle organizzazioni possano influenzare l'efficacia e l'efficienza dell'adozione tecnologica.*

Inoltre, i risultati dello studio forniscono evidenze empiriche che illuminano aspetti poco noti dell'intersezione tra Gen-AI e agri-food, presentando implicazioni teoriche e manageriali significative. La dimostrazione di come il vantaggio relativo percepito e il sostegno attivo del top management agiscano come leve cruciali per facilitare l'integrazione della Gen-AI nel settore agri-food, offre un contributo sostanziale alla comprensione delle strategie di adozione tecnologica. Questi risultati contribuiscono ad implementare la letteratura esistente e forniscono, ulteriormente, elementi per ricerche future, incoraggiando ulteriori indagini sull'impatto delle variabili organizzative e di leadership nel contesto dell'innovazione tecnologica nel settore agri-food.

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Managing services in tourism destinations through Artificial Intelligence and Machine learning: The Data for Destination Model

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Abstract

How can services in tourism destinations be successfully managed? Addressing this question is crucial in tourism management given the significant role played by destinations' multi-level actors in shaping development paths worldwide. Some paths generate positive environmental, economic and social effects for all the actors involved, thus appearing sustainable, while others have negative implications in terms of sustainability. It is also relevant for competitiveness of both firms and destinations. The understanding and managing of the complex interactions connected to multi-dimensionality of tourism destinations is crucial, although currently posited as a major knowledge gap, by both scholars and practitioners. In response, this study proposes and applies a data-driven approach to Destination modeling, developed by the authors together with the Italian Institute for Tourism Research following the participatory action research approach. The proposed model is based on two key assumptions: 1) tourism destinations can be understood as socio-ecological systems where relationships among the multi-level actors involved are of dialectical nature, thus requiring mutual adaptation, and 2) data about such relationships can be gathered and made available to structure, systematize and organize a huge range of information according to complex artificial intelligence and machine learning processes. Once real time information is integrated from various sources it can drive complex analysis about the supply and demand sides of tourism destinations. Preliminary results emerging from the application of the proposed model confirm its large application for decision makers and policymakers to adopt shared adaptation strategies, suitable for creating environmental, economic and social, value. The on-line and real time access to the above intelligent services can help inter-organizational knowledge transfer processes, strategic intentionality, multi-stakeholder decision making, systemic approach, social responsibility, and tourist experience of decision makers and policymakers.

Key words: *Tourism services; Artificial Intelligence; Machine Learning; Destination management model; Sustainable tourism; Participatory action research approach.*

Framing of the research. *How can services in tourism destinations be successfully managed? Addressing this question is crucial in tourism management given the significant role played by destinations' multi-level actors in shaping (un)sustainable development paths worldwide (Bramwell et al., 2017; UN, 2015). This role concerns tourism firms, various other organizations, local and multi-local institutions, local communities, and tourists that by interacting each other co-determine the tourism offering enhancing (or not) regional identities within destinations, thus competitiveness (Aldebert et al., 2011; Beritelli et al., 2014; Paniccia and Baiocco, 2021).*

Over the last decades, great efforts of research have been devoted to analyzing the main structural characteristics of destinations together with the key phases of their life cycle, where collaboration between firms and institutions is crucial (Butler, 1980; Kubickova and Martin, 2020). In this regard, attention has been given to elaborating conceptual models and set of indicators aimed at analyzing and enhancing the capacity of tourism destinations to create shared value (Porter and Kramer, 2011) by activating synergies at both local and multi-local levels among the aforesaid actors (e.g., Crouch and Ritchie, 1999; Dwyer and Kim, 2003; Enright and Newton, 2004; Mazanec et al., 2007, Hong, 2008; Knežević Cvelbar et al., 2016).

What emerges from the analysis of prior models is that while scholarly consensus exists on the importance of considering the influence of interconnected factors—institutional, industrial, and natural types— that are unique and

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distinctive of the local contexts of a destination to progress toward sustainability (Norgaard, 1994) and thus for competitiveness, the complexity of the interactions among the various multi-level actors of a destination (Benson, 1977; Baiocco and Paniccia, 2023) is still not completely taken into consideration. Significantly, the majority of prior models focus on the supply-side of the destination without considering it in connection with the side of the demand (Volgger et al., 2021). Also, the level of digital transformation of tourism destinations is still limitedly considered (Ribeiro et al., 2020) and most of the proposed indicators are difficult to be calculated given the limited availability of data at local levels (Font et al., 2023).

Clearly, the direct applicability of such models results limited, as it is the possibility for decision makers and policymakers to share updated and adequate information able to trigger interactive learning processes (Paniccia et al., 2024) and support the creative use of the specific factors of each tourism destinations (Pilotti et al., 2013; Donthu et al., 2020, Paniccia and Baiocco, 2021).

Purpose of the paper. *This study proposes and applies a data driven approach to model destinations (Data for Destination model, also DfD, hereafter), developed by the authors in collaboration with the Italian Institute for Tourism Research (ISNART). DfD aims to provide decision makers and policymakers with an ecosystem of digital services to better observe, comprehend and manage the complex interactions associated with the multi-dimensionality of tourism destinations.*

Methodology. *The DfD Model was developed during the period December 2022-March 2024 following the participatory action research approach (Whyte, 1991). This approach involves researching with practitioners, to collectively bring about desirable changes in the object of analysis - in this case, the DfD Model - through iterative cycles of action and reflection. In particular, researchers involved are from different disciplines, namely management, computer science, and statistics with previous research in the field of sustainable tourism management, artificial intelligence, and machine learning. Practitioners come from ISNART, that is the organization of the Italian Chamber System with the mission of supporting the Chambers of Commerce particularly in the activities related to the "enhancement of cultural heritage as well as development and promotion of tourism" introduced by the Italian law in 2016, and Reveal srl, a spin-off company from Tor Vergata University of Rome specialized in artificial intelligence technologies.*

Accordingly, the two key assumptions underlying the model are the following.

First, tourism destinations can be understood as socio-ecological systems constituted by a plurality of reciprocally functional sub-systems where inter- and intra-relationships are of dialectical nature (Paniccia and Baiocco, 2021; Baiocco et al., 2023). This means that the dynamics of interactions and mutual feedback between multi-level actors of a destination (i.e., tourism firms, various other organizations, local and multi-local institutions, local communities, and tourists) drive the development of the destination tourism offering capable (or not) to satisfy tourist needs and also to create environmental, economic and social value for all the actors involved. In this context, inter-organizational knowledge transfer processes, strategic intentionality, multi-stakeholder decision making, systemic approach, social responsibility, and tourist experience have been identified as key determinants of effective co-evolutionary adaptations between the various actors at multiple levels within destinations (Paniccia and Leoni, 2019; Cristofaro et al., 2020).

Second. Artificial intelligence (Turing, 1950; Brachman and Levesque, 2004) and machine learning (Mitchell, 1997) can be effectively used to collect and integrate real-time data about the aforementioned phenomena from heterogenous sources and timely create large bodies of location specific economic, social and cultural information and knowledge. These allows to automatically structure, design and organize a data lake explicitly modeling a huge range of phenomena about tourism destinations. The data lake integrates all evidences according to a complex knowledge model that aims at support the later information processing steps such as classification and clustering of tourism phenomena, inference in What-If analysis, sentiment and reputation assessment (Mehraliyev et al., 2020; Wankhade et al., 2022; Basile et al., 2018) as well as economic forecasting.

Based on the above, the DfD Model provides the logical structuring of the data according to an explicit knowledge representation formalism (Brachman and Levesque, 1980) and can be thought of as a set of integrated knowledge graphs, including:

- *Tourism Destinations represented on the basis of the multidimensional homogeneous characteristics of their corresponding municipalities, regardless of whether these municipalities are geographically connected or not. Such representation operates on municipalities characterized by the number of inhabitants, and it thus allows to distinctively describe: small municipalities (up to 15 thousand inhabitants), medium municipalities (over 15 thousand inhabitants up to 50 thousand inhabitants), large municipalities (over 50 thousand inhabitants up to 400 thousand inhabitants), metropolis (over 400 thousand inhabitants). Such breakdown of destinations by size is one qualifying aspect for DfD Model, as it supports consistent comparison across meaningful contexts (e.g., similar in size) and measure in different and specific manners destinations, such as Rome, with respect to others based on suburbs or small municipalities.*
- *Tourism-related phenomena as explicit and measurable characteristics of destinations, such as, economic descriptors (e.g., the municipal expenditure for tourism development), cultural heritage sites, industrial factors such as the levels of investment, the typology of industries or the distribution of accommodation/gastronomic services specific to a target destination, and finally, reputation indexes, directly observable from digital tourism services (travelers' reviews) or from newspaper.*
- *A complex relational model that allows to model multidimensional economic facts (quantitative indicators) about individual tourism destinations as evidences emerging from the controlled integration of large bodies of data across the Italian system of destinations along time, that is:*

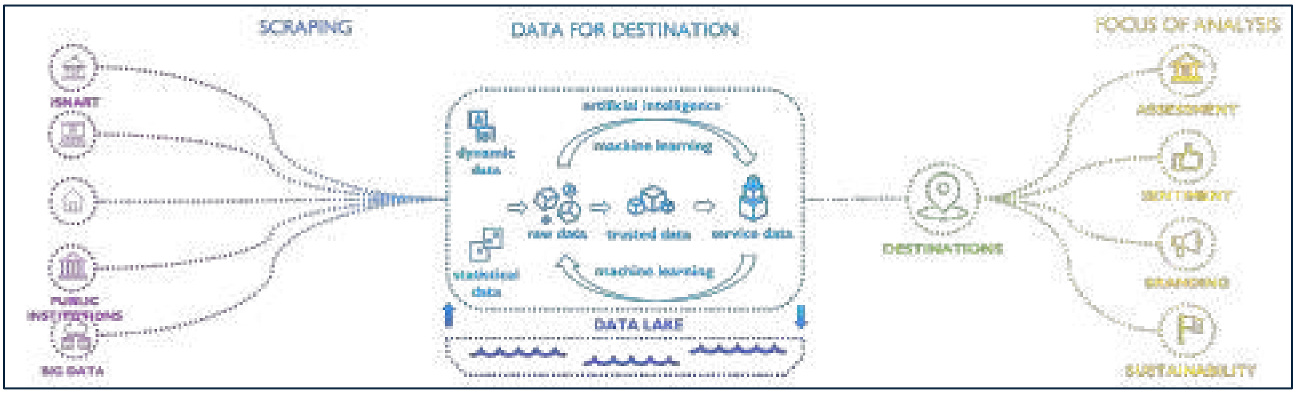
- *sets of indicators on tourism dimensions and their relative importance (weight) allow the systems to detect and measure the relative importance a dimension has in relation to the specific tourism destination under evaluation;*
- *positional distributional metrics are used to compare destinations, i.e., to consistently represent how an individual municipality ranks on a specific aspect of the tourism destination under evaluation. This measure is quantitative but mainly relative, as it is computed with respect to other destinations that are part of similar clusters (e.g., destination of similar dimensions).*
- *a clear model for the individual indicators related to a tourism destination that makes each dimension/indicator immediately comparable with that of other tourism destinations.*

Furthermore, DfD is supported by a software system integrating different artificial intelligence services discussed in Croce et al. (2013), Castellucci et al. (2016), Filice et al. (2018) designed to structure, systematize and organize the single data lake currently including: i) approximately 45.5 million statistical and dynamic open data coming from various certified sources (including Istat, Bank of Italy, Infocamere) covering 100% of Italian municipalities (7,926) classified by Istat (2022) considering their tourism density, ii) about 4 million reviews and iii) 708,000 scraped web pages.

The overall data organized in the platform allows to derive 74 different variables expressing crucial information for four different focuses of analysis, namely:
- *the integration of destinations' tourism offering by considering quantitative data related to six pillars, namely tourism products, tourists, infrastructures, firms, local community, and governance (Assessment focus of analysis).*
- *the satisfaction of tourists through the analysis of their so-called sentiment associated with attractions, activities and products of the destination conducted using natural language processing and machine learning techniques (Sentiment focus of analysis);*
- *the positioning, reputation and engagement of the destination brand by using dynamic data from local and national media (Branding focus of analysis);*
- *the environmental, social and economic impacts brought about by tourism development in the local context of a destination by using quantitative data (Sustainability focus of analysis).*

A logical architecture for DfD can be represented as in Figure 1.

Figure 1. Logical architecture of DfD Model



Results. *In this section we present the four focuses of analysis of the Model and apply them to the Italian destination called "Costa dei Trabocchi", as a concrete example of operational use of the system. This destination consists of nine municipalities located along the coast of the Abruzzo Region in southern Italy. At the end of 2022, this Region contributed a 3% share to the tourism demand aimed at southern Italian regions including islands (Banca d'Italia, 2023). As of the same date, more than 15,000 tourism firms and 57,000 tourism employees were active in the Region, accounting for 7.6% and 8.1%, respectively, of the tourism firms and employees in southern Italy including the islands (ISNART, 2023).*

<u>Assessment focus of analysis</u>
This focus of analysis allows to evaluate the integration of destinations' tourism offering by calculating a specific set of indicators related to the following six pillars:
- *Tourism products, including the tangible and intangible resources of a destination in relation to both the ability of the destination to attract tourists and the usability of such resources by tourists;*
- *Tourists, representing the tourism demand attracted by the destination considering tourists' types, motivations, flows and related seasonality;*
- *Infrastructures, that is the accessibility (physical and digital) of the destination by considering toll booths, train stations, civil airports, ports, wireless and fiber optic infrastructure for Internet connection, and the level of internal mobility (public and private) of the destination;*

- *Firms, including the size, characteristics and dynamics of firms in the business fabric of the destination both in general and in relation to the tourism supply chain;*
- *Local community, that is the characteristics of the local community including its relationships with tourism firms and institutions;*
- *Governance, that is the degree to which institutions, firms and various destination actors share strategies and objectives referred to the tourism sector.*

Thus, in addition to factors related to the supply-side of the tourism destination traditionally considered in prior models (e.g., Crouch and Ritchie, 1999; Hong, 2008; Knežević Cvelbar et al., 2016), the Model allows to consider some specific aspects of the tourism demand as recommended by scholars (Volgger et al., 2021) as well as the level of digital transformation of destinations (Ribeiro et al., 2020).

Table 1 identifies pillars and related indicators of the Assessment focus of analysis and its application to Costa dei Trabocchi.

Table 1. Assessment focus of analysis applied to Costa dei Trabocchi

Pillars	Indicators	Indicator Assessment	Pillar Assessment
Tourism products	Index of cultural places attractiveness	20%	57%
	Touristicity Index	80%	
	Index of tourism attractors popularity	80%	
	Municipal expenditure for tourism development	80%	
	Municipal expenditure for the protection and enhancement	20%	
Tourists	Index of tourism density	80%	79%
	Share of international tourism	60%	
	Trend of tourism attendance over the last 5 years	80%	
	Average attendance of tourists	95%	
Infrastructures	Reachability index	80%	55%
	Internal mobility index	95%	
	Presence of rail infrastructure	20%	
	Presence of fiber connection	40%	
	Presence of wireless connection	20%	
	Municipal expenditure for transportation	20%	
Firms	Consistency of the business fabric	40%	68%
	Vitality of the business fabric	40%	
	Consistency of the tourism supply chain	60%	
	Relevance of the tourism supply chain	80%	
	Change in the tourism supply chain	80%	
	N. of accommodation firms (hotel and non-hotel)	80%	
	N. of bed-places (hotel and non-hotel)	80%	
	N. of catering firms	80%	
	Consistency of the business fabric	60%	
Local community	Age index	60%	71%
	Depopulation rate over the past 20 years	60%	
	Participation in local elections	60%	
	N. of Airbnb facilities (accommodation/rooms)	80%	
	Social security index	95%	
	N. of employees working in the tourism sector	60%	
	Average revenue of Airbnb facilities (accommodation/rooms)	80%	
Governance	Application of tourist tax	60%	61%
	Vitality of local government	60%	
	Municipal investment in roads and streets	20%	
	Event planning	20%	
	Municipal investment for protection and enhancement of municipal assets and activities	95%	
	Recognitions and memberships (e.g., certifications, membership in associations)	40%	
	Application of tourist tax	95%	
Integration level of the destination's tourism offering			65%

Overall, the integration level of the tourism offering of Costa dei Trabocchi is 65%, ranking in the fourth quintile of measurement, reflecting the fact that none of the six pillars rank in the highest quintile of measurement.

The highest value is recorded by the set of indicators related to the tourist pillar (79%) followed by the local community pillar (71%), both in the fourth measurement quintile. Likewise, the firm and governance pillars record overall values within the fourth measurement quintile (68% and 61% respectively) signaling particular areas of attention, i.e., the consistency and vitality of businesses fabric and municipal investment in roads and streets and event planning.

The need for ameliorating actions in these areas is confirmed by the value recorded by the infrastructure and the tourism products pillars (55% and 57% percent) both in the third quintile of measurement. Tthe infrastructure pillar reflects the critical issues related to both physical (particularly, rail infrastructure) and digital (mainly, wireless) accessibility, as well as spending by municipalities on transportation. The tourist products pillar shows limited attractiveness of museums, monuments, archaeological areas and state museum circuits and low municipal spending on the protection and enhancement of cultural goods and activities.

<u>Sentiment focus of analysis</u>

The sentiment focus of analysis follows the methods discussed in Croce et al. (2013) and Castellucci et al. (2016) by which the level of tourists' satisfaction is analyzed with reference to particular aspects of tourism destinations offerings. In particular, through the analysis of perceptive data conducted using natural language processing and machine learning techniques, this focus of analysis allows to investigates the so-called tourist sentiment associated with attractions, activities and products (e.g., snow, nature tourism, wellness) of tourism destinations. Perceptions of services offered by firms, experiences lived in the destination and the tourism destination as a whole are the dimensions of tourists' sentiment considered by the DfD Model to which various sub-dimensions are associated.

For each of the above sentiment dimensions, the system estimates a polarity judgment (positive, neutral, negative). Taking these dimensions into account consists in considering what makes a destination competitive (or not) for those who have decided to visit it, as recommended in Cronjé and Plessis (2020).

Thus, this focus of analysis appears particularly useful for assessing the engagement capability of tourism firms as well as of destinations and the online reputation of both. It is worth noting that this type of analysis is still scarcely used in the tourism sector despite the fact that it is one of the most influenced by online reputation (Ali et al., 2021).

Table 2 identifies dimensions and sub-dimensions of the Sentiment focus of analysis related to Costa dei Trabocchi.

Table 2. Sentiment focus of analysis applied to Costa dei Trabocchi

Sentiment dimensions	Sentiment sub-dimensions	Subdimension satisfaction	Dimension satisfaction
Perception of services	Cost	95%	70%
	Pollution/Cleaning	95%	
	Rental	95%	
	Personnel	60%	
	Typical products	95%	
	Health and wellness	0%	
	Services	80%	
	Accommodation	0%	
	Catering	80%	
	Commercial activities	95%	
	Information	80%	
	Events organization	95%	
	Tourist guide services	40%	
Individual perception	Emotional dimension	95%	84%
	Artistic dimension	95%	
	Naturalistic dimension	95%	
	Food and wine dimension	80%	
	Physical dimension	60%	
	Experiential dimension	60%	
Overall perception	Availability	95%	91%
	Organization	80%	
	Reachability	95%	
	General	95%	
Satisfaction level of tourism demand			***77%***

The level of satisfaction of tourism demand regarding the offer of Costa dei Trabocchi is of 77% in the fourth quintile of measurement.

In view of the positioning of the dimensions "overall perception" and "individual perception" in the best quintile of measurement, the indicated level of satisfaction of tourism demand seems to be mainly affected by the judgments expressed with reference to the perception of the quality of services. In this regard, tourists' negative judgments associated with this dimension amount to 29% of the total judgments made (Figure 2) compared with 14% of the negative judgments associated with the individual perception (Figure 3) and overall perception (Figure 4) dimensions. It is worth noting that individual perception is associated with a high percentage of neutral judgments (21%) relative to the experiential dimension.

Figure 2. Perception of services - Costa dei Trabocchi

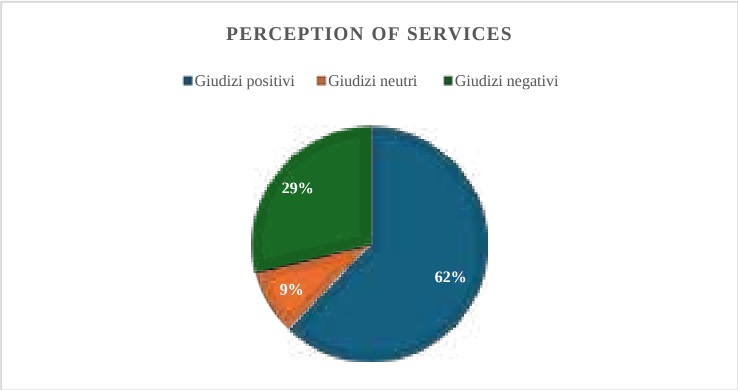


Figure 3. Individual perception - Costa dei Trabocchi

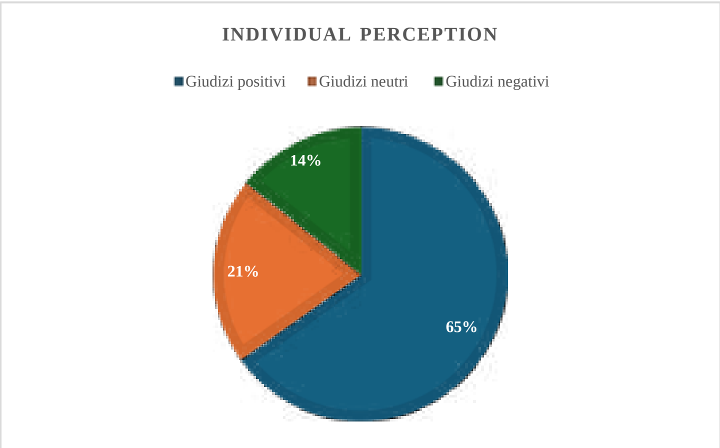
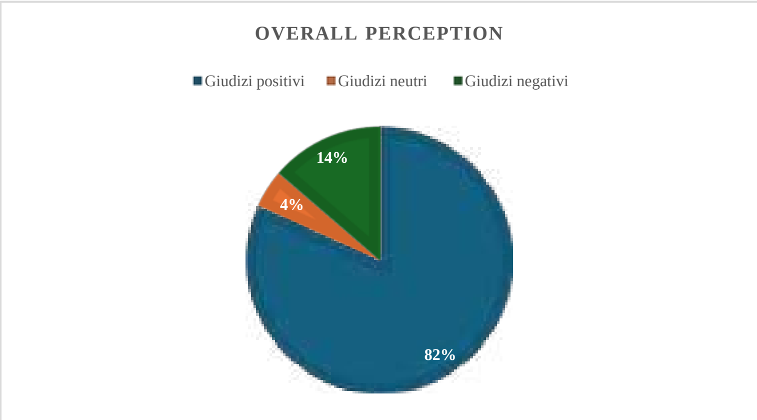


Figure 4. Overall perception - Costa dei Trabocchi



<u>Branding focus of analysis</u>

This focus of analysis makes it possible to assess the attractiveness of tourism destinations through a dynamic dataset from local and national media according to methodologies.

Specifically, what is here considered are the quantitative, the perceptual and the dynamic dimensions of destination attractiveness, by taking into account relevant news in local and national media related to tourism and culture, safety, and environment. Media news are automatically classified according to Croce et al. (2013), Castellucci et al. (2016), and Filice et al. (2018) along the following semantic dimensions:
- tourism and culture: events, culture, tourism;
- security: robberies, riots, scams, mafia, accidents, traffic, feminicides, serial murders, racism, violence;
- environments: disasters, climate and pollution.

As a consequence, the branding analysis provide information on the positioning, reputation and engagement of the destination brand, that are acknowledged as necessary elements for strong brand value (including monetary value) to be achieved (Kotler et al., 2017).

Table 3 identifies dimensions and sub-dimensions of the Branding focus of analysis and its application to Costa dei Trabocchi.

Table 3. Branding focus of analysis applied to Costa dei Trabocchi

Branding dimensions	Branding sub-dimensions	Branding sub-dimension Outcome	Branding dimension Outcome
Quantitative *Volume of relevant news on tourism and culture, safety and environment (Positioning)*	Positioning tourism and culture	60%	66%
	Positioning safety	60%	
	Positioning environment	80%	
Perceptive *Volume of relevant news with "positive" or "negative" impact on tourism and culture, safety and environment (Reputation)*	Reputation tourism and culture	95%	95%
	Reputation safety	95%	
	Reputation environment	95%	
Dynamic *Trend period T/period T - Δ of relevant news on tourism and culture, safety and environment (Engagement)*	Engagement tourism and culture	95%	95%
	Engagement safety	95%	
	Engagement environment	95%	
Level of tourism appeal			***85%***

The level of tourism appeal of Costa dei Trabocchi is of 85% percent in the fifth measurement quintile. The appeal of the destination is affected by the value of the quantitative dimension (66%), which is in the fourth quintile of measurement. In turn, this dimension is particularly affected by the volume of relevant news about safety and tourism and culture. The perceptual and dynamic dimensions of Costa dei Trabocchi attractiveness signal the destination's good reputation and capacity for engagement in all areas considered (tourism and culture, safety and environment).

<u>Sustainability focus of analysis</u>

The Sustainability focus of analysis, still under development at the time of this study, makes it possible to assess through quantitative data analysis the environmental, economic, and social impacts of tourism destination development.

In particular, this focus of analysis addresses the need to create indicators related to the three dimensions of sustainability (European Commission, 2016; Baiocco et al., 2013) by helping to enrich existing models mainly focused on single dimensions or at most two of the three. Finally, taking into consideration the local dimension of sustainable development (Norgaard, 1994), the focus of the analysis is on the interdependencies and interactions among the three dimensions of sustainability at the local level of tourism destinations and the impact therein determined by the tourism phenomenon as a lever to progress towards (un)sustainability by bringing out (or not) the system of local qualities (Pilotti et al., 2013; Donthu et al., 2020).

Table 4 identifies sustainability dimensions and indicators implemented so for by the Model.

Table 4. Sustainability focus of analysis

Sustainability dimensions	Sustainability indicators
Environmental	Index of municipal land consumption Index of municipal fragmentation Index of population density per km^2 Index of waste attributable to municipal tourism consumption Index of municipal waste collection related to tourism
Economic	Municipal per capita income Municipal entrepreneurship index Employment in the tourism sector at municipal level
Social	Index of municipal tourism pressure Average length of stay of tourists at municipal level Index of local community social responsibility index Index of corporate social responsibility

Research limitations. *The DfD Model is fully developed except for the Sustainability focus of analysis that is still under construction. Moreover,* future developments include the introduction of additional destinations' classification criteria that take into account, for example, other structural characteristics of destinations (e.g., destinations in rural, urban, seaside, mountainous areas) and specific market targets (including art cities, boroughs, winter sports resorts, hiking and walking, seaside). Also, an extended model that integrates Assessment, Sentiment, Branding and Sustainability focuses of analysis is under consideration.

Managerial implications. *The application of the Model helps to identify Costa dei Trabocchi as a destination endowed with specific natural, cultural, social and economic factors capable of attracting and satisfying tourism demand whose potential however is only partially exploited. This destination can thus be considered as a system in the process of completion (Barile et al., 2018; Paniccia and Baiocco, 2021). In fact, what emerges is the need for more effective interactions between the various actors operating at multiple levels of Costa dei Trabocchi in order to overcome the main critical issues related to physical and digital accessibility and the lack of coordinated initiatives to ensure the safety of places as well as their promotion.*

Moreover, and in connection with the above, the DfD focuses of analysis have generated a wide range of relevant, reliable, comparable, up-to-date information related to multiple aspects of the destinations under analysis. Such information is particularly useful for planning ameliorating actions. This is in line with the need highlighted in the tourism literature for appropriate methodologies, specific indicators, and associated targets for ongoing verification of achievements (Font et al., 2023; Baiocco and Paniccia, 2023).

Thus, preliminary results emerging from the application of the Model suggest to consider it a valid tool for decision makers and policymakers to solve common problems by sharing plans and coordinating actions (inter-organizational knowledge transfer processes). In fact, understanding the mutually functional relationship that binds the multiple actors operating at multiple levels of a tourism destination helps the strategic intentionality of both decision makers and policymakers to cooperate, involving also communities, bringing different skills and professionalism to bear on integrated actions and implementing strategies by having a common vision of the vocations of the places. We derive from this the usefulness of the model in supporting careful planning of the enhancement of destinations and firms' identities based on integrated actions that require the different actors in the destination to equip themselves with flexibility, adaptability and durability (systemic approach and multi-stakeholder decision-making processes). In this context, the Model is also useful for designing interventions oriented toward the sustainable development of the destination (social responsibility), based on a balanced relationship between environmental, economic and social needs.

Furthermore, the DfD helps to intercept, in satisfactory quantitative and qualitative terms, relevant segments of tourist demand (tourist experience). Particularly, the Sentiment focus of analysis appears useful in identifying which segments of tourism demand can find the highest satisfaction in relation to the destination offering. Also, the aforementioned focus of analysis offers to decision makers and policymakers an important knowledge base for a serious and professional work of self-reading in an identity key, reconnaissance of their resources and their strategic reorganization taking into account the perceptions that tourists have regarding the quality of services, the lived experience and the destination as a whole. In connection with the above, the branding focus of analysis is particularly useful for thinking about the message to be conveyed about the tourist destination offering by emphasizing the relevance of places in relation to relevant segments of tourist demand. The Model also allows for continuous feedback processes, i.e., analysis, evaluation and monitoring of the actions carried out and in particular of the effects of these on the sustainability, and thus on competitiveness of both firms and destinations, to ensure that the actions taken endure, and improve, over time.

Originality of the paper. This paper discusses a methodological framework and a complex software system that responds to a lively need in tourism management research and practice. It allows to better and concretely *understand how the complex interactions connected to multi-dimensionality of tourism destinations can be effectively managed. In doing so, it adopts an inter-disciplinary approach integrating machine learning and artificial intelligence methods (Croce et al, 2013; Filice et al., 2018) with economic modeling of the phenomena, whose particular value allows to deal with the increased complexity in tourism (Paniccia and Baiocco, 2021; Volgger et al., 2021).*

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The Future of Digital Technologies: AI-Driven Interfaces for Universal Usability

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Abstract

In the evolving landscape of digital technology, the integration of Artificial Intelligence (AI) into user interface design has emerged as a pivotal factor in democratizing access to technology and enhancing user experience. This paper investigates the transformative impact of AI-driven conversational interfaces on the design and usability of digital platforms, with a particular focus on engaging the next generation of users. Through a quantitative study involving 200 young individuals, we explore their perceptions, experiences, and expectations regarding current navigation interfaces and future paradigms of user interaction. The research highlights a paradigm shift towards conversational models that facilitate more intuitive, personalized, and engaging online searches, transforming the act of seeking information from a transactional process into an interactive learning journey.Our findings suggest that AI has the potential to significantly enrich user interface design, making digital experiences more accessible and enjoyable across diverse demographic groups. This paper contributes to the literature by offering new insights into the role of AI in creating inclusive digital environments and setting the stage for future investigations into the democratization of technology access. By bridging a critical gap in existing research, this study not only enriches the academic discourse but also provides practical guidance for leveraging AI to enhance user engagement and interface design in the digital age.

Key words: *Society 5.0; digital divide; universal design; AI-driven interfaces; democratization of technology.*

Framing of the research. *Emerging technologies have transitioned from being mere accessories to necessities in what is now termed Society 5.0 - a concept that integrates technology into daily life for a sustainable future. Holford (2019) emphasized the role of technology in fostering creative organizations, highlighting its increasing impact on business activities and the opportunities it presents. Human Computer Interaction research, with its roots in diverse fields such as computer science, communication, and psychology, has played a pivotal role in enhancing our understanding of the interaction between humans and technology, particularly as it relates to management information systems (Zhang & Li, 2005; Germonprez et al., 2009).*

However, as Dai (2009) noted, the adoption of Digital Technologies (DTs) varies across companies of different sizes and structures. Nieto and Fernandez (2005) further explored this disparity, pointing out that while large companies are well-equipped to harness technology, small and medium enterprises (SMEs) could benefit even more due to their limited access to resources and markets. This resource limitation has widened the technological adoption gap, making insights into the impact of Internet usage on efficiency and competitiveness crucial for SMEs in the global knowledge economy. The growing era of Human-AI Interaction adds a new dimension to this landscape, as AI becomes an agent with decision-making capabilities, affecting working and everyday lives (Virvou, 2022). A recent study by MIT Sloan Management Review found that more than 80% of organizations see digital technologies such as AI as a strategic opportunity, and almost 85% see AI as a way to achieve competitive advantage (Ransbotham et al., 2017). Buoyed by recent advances in machine learning, the general field of AI is well-positioned to solve problems across diverse domains, and it has been referred to as the most important general-purpose technology of our era (Erik Brynjolfsson et al., 2017). Regarding the adoption of digital technologies, two distinct research streams have emerged over time: technology as a Universal Design and the digital divide theory (Van Dijck, 2003). On one side Universal Design (UD), as defined by Tobias (2003), originally aimed to make the internet accessible to people with disabilities, identifying the high prices and scarce information as barriers. However, Stephanidis (2022) expanded this concept, arguing that UD is not just about disabilities but about inclusivity for all, evident in its application across various engineering disciplines.

On the digital divide front, Van Dijk and Hacker (2003) identified several barriers to widespread technology adoption, including lack of digital experience, absence of computers and network connections, insufficient digital skills, and lack of significant usage opportunities. They highlighted the user-unfriendliness of PCs and networks as major obstacles to

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adoption by companies and individuals. As we consider the implications of these theories, the contributions of Human Computer Interaction and AI to the theory and practice of user interfaces become increasingly relevant, calling for more research on trustworthy and explainable AI to ensure usability in human-machine interactions (Virvou, 2022; Germonprez, Hess, & Russo, 2009).

This work delves into the evolution of Human-Computer Interaction (HCI) theory, illustrating that there was, and continues to be, an opportunity to systematically enrich the existing body of HCI knowledge and design practices. It emphasizes how the development of toolkits is already underway, bringing complex technologies like Artificial Intelligence (AI) to the masses. Furthermore, the chapter sheds light on the importance of these toolkits by examining their ongoing impact and identifying limitations when deployed in real-world scenarios, a concept explored by Dibia et al. (2019).

Democratization of technology

The challenge of ensuring universal access to technology and equipping individuals with the necessary skills to navigate the digital landscape has been an ongoing issue. The literature is replete with evidence suggesting that usability and user experience are critical determinants of technology acceptance and adoption (Nielsen, 1993; Davis, 1989). Users frequently encounter obstacles when navigating poorly designed interfaces, leading to frustration and abandonment of potentially valuable digital tools (Norman, 2013). Additionally, the rapid pace of technological advancement has outstripped the rate at which non-technical users can acquire the necessary skills, further exacerbating the divide (Von Krogh, 2018).Stephanidis (2022) has highlighted the critical need for a solid R&D agenda for universal access to Information Society Technologies, an objective that has started to feature systematically in the research agendas of institutions and national funding agencies. Shneiderman (2000) further argues that achieving broad user reach is not just a democratic ideal but also a strategic business decision. He underscores the importance of universal usability in computing services, which, given their complexity and the diverse applications requiring high interactivity, is essential.

In light of this context, the case of Windows 95 emerges as a prime example of how usability can be a decisive factor in the mass adoption of technology. The Windows 95 project's commitment to iterative design, usability testing, and problem tracking significantly reduced barriers to personal computing, making it more accessible to a broader audience (Sullivan, 1996). This approach not only enhanced user satisfaction but also set a precedent for future technologies to emulate. Building on this legacy, AI, particularly through advancements in Natural Language Processing (NLP), is set to continue this trend by bridging the gap between human language and machine understanding, offering a more intuitive and seamless interface for human-computer interaction (Shivahare et al., 2022; Adam M Sanadi and Venkatesh Bhat, 2022). Natural Language Processing (NLP) is a critical discipline within artificial intelligence that bridges computational techniques with human language, enabling machines to interpret, generate, and respond to human text and speech (Hirschberg & Manning, 2015). This field integrates concepts from computer science and computational linguistics, providing the foundation for a range of applications from machine translation and sentiment analysis to chatbots and virtual assistants (Young et al., 2018) Banane and Erraissi (2022) define NLP as the intersection of computer science and linguistics, broadening its applications to include functions like automatic translation, sentiment analysis, and chatbots, thus further democratizing access to technology. Moreover, the integration of NLP with another emerging technology, big data, marks a significant development. Banane and Erraissi (2022) observed also that big data has transformed NLP researchers into data scientists, capable of choosing the right data representations. The Casablanca Artificial Intelligence Observatory noted the impact of Big Data on NLP, particularly in providing access to the semantic content of textual data and combining the two technologies to process massive NLP data. In conclusion, the democratization of technology, facilitated by AI and NLP, is a crucial step towards making technology accessible and user-friendly, thereby enabling companies and individuals to remain competitive and updated in the job market. This integration could be a significant stride towards achieving technological democratization, especially with the advent of Web 3.0 and digital technologies. Finally, other technologies such as Blockchain technology could follow in these footsteps, as user-friendly interfaces are anticipated to facilitate its mainstream adoption, as forecasted by Tapscott and Tapscott (2016), reinforcing the importance of usability for technological uptake.

Purpose of the paper. *The central aim of this paper is to examine the dynamic interplay between emerging technologies and their integration into Society 5.0, emphasizing the pivotal role of Human Computer Interaction (HCI) and Artificial Intelligence (AI) in bridging the gap between technological innovation and user accessibility. This research seeks to contribute to the ongoing discourse on technological democratization, exploring how advancements in machine learning, natural language processing (NLP), and big data can significantly enhance the usability and user experience, thus fostering broader technology acceptance and adoption. This paper sets out to explore two main research streams: the concept of technology as a Universal Design (UD) and the implications of the digital divide. By examining the evolution of HCI theories and practices alongside the burgeoning field of AI, this work aims to underscore the necessity of developing toolkits that make complex technologies more accessible to the general populace. Moreover, it endeavors to identify the limitations of current technological implementations in real-world scenarios, thereby informing future design and development efforts.*

Additionally, the work will explore the transformative potential of NLP in making technology more intuitive and aligned with human language, thus contributing to the democratization of technology. Ultimately, the analysis of NPL as a transforming technology from the lens of HCI and Universal Access aspires to advance the understanding of how emerging technologies can be harnessed to foster a more inclusive and sustainable future, in line with the principles of Society 5.0.

Methodology. *This study will adopt a cross-sectional, descriptive research design using a quantitative methodology. The primary objective is to quantify and analyze the perceptions, experiences, and expectations of a young demographic regarding current and future user interfaces, with a special focus on the impact of Natural Language Processing (NLP) and Artificial Intelligence (AI) technologies. This approach enables the researchers to capture a snapshot of the evolving user-interface landscape through the lens of the next generation of users.*

In collaboration with a leading AI consultancy firm, the authors developed a structured questionnaire designed to capture a broad spectrum of experiences and expectations related to navigation interfaces. The questionnaire encompassed various dimensions such as:

- ***Ease of Use**: Questions designed to assess how intuitively users can navigate and utilize interfaces without prior training or instruction.*
- ***Intuitive Design**: Items focused on evaluating the naturalness and simplicity of the interface design, facilitating a seamless interaction.*
- ***Personalization Capabilities**: Queries to understand the importance and effectiveness of interface personalization in enhancing the user experience.*
- ***Role of NLP and AI**: Questions aimed at gauging the perceived benefits and potential of NLP and AI technologies in making interfaces more responsive, interactive, and human-like.*

Sampling and Data Collection

The study targeted a sample of 200 young individuals aged between 13 and 18 years, identified through purposive sampling to ensure a focus on the next-generation users who are at the forefront of adopting and interacting with new technology. This age group is particularly relevant given their native digital fluency and potential to shape future technology trends. The questionnaire was administered online, leveraging digital platforms popular among the target demographic to ensure a high response rate and engagement.

Data Analysis Approach

Upon collecting the responses, the data will be subjected to rigorous statistical analysis. The initial step will involve descriptive statistics to summarize the data, followed by inferential analyses to examine relationships and differences within the data. Specifically, the study will employ:

- ***Factor Analysis**: To identify underlying variables (factors) that explain the pattern of correlations within the observed variables, particularly relating to usability and interface design preferences.*
- ***Regression Analysis**: To explore the predictive relationships between demographic variables (e.g., age, tech-savviness) and key outcomes related to expectations for future interfaces and the perceived role of AI and NLP.*
- ***ANOVA (Analysis of Variance)**: To compare the responses across different groups within the sample, if applicable, to identify any statistically significant differences in perceptions and expectations.*

Ethical Considerations

Given the involvement of minors, the study adhered to stringent ethical guidelines, including obtaining informed consent from parents or guardians and ensuring the anonymity and confidentiality of respondents.

The methodology outlined provides a robust framework for exploring the intricate dynamics between young users and digital interface technologies. By analyzing the nuanced feedback from this demographic, the study aims to contribute valuable insights into designing future interfaces that are not only technologically advanced but also deeply aligned with user expectations and preferences.

Results. *The anticipated outcomes of this research project suggest a transformative shift in the realm of online navigation experiences, especially among the younger generation, whose digital behaviors are poised to redefine the norms of interaction with digital technologies. This shift is largely driven by the sophisticated integration of Artificial Intelligence (AI) into the fabric of user interface design, marking a departure from traditional, linear search methodologies towards a dynamic, conversational interaction paradigm. Specifically, in this emerging paradigm, the act of searching online is expected to evolve from a perceived 'loss' of time—often associated with the mechanical act of querying and sifting through results—to being considered a meaningful 'investment' of time. This reevaluation is rooted in the premise that searches, through AI-enhanced conversational interfaces, offer not just answers but also a pathway to discovery and learning. The initial search intent thereby unfolds into a broader educational journey, where the acquisition of knowledge is complemented by an exploratory and interactive engagement with information. Central to this paradigm shift is the role of AI-driven chat interfaces that simulate a natural, human-like conversation with users. These interfaces are designed to comprehend queries in a nuanced manner, engage users in a dialogic interaction, and provide responses that are not only accurate but also contextually relevant. This level of interaction facilitates a more intuitive and engaging information-seeking process, where queries lead to conversations, and conversations pave the way for personalized learning experiences. Moreover, AI's capability to offer personalized recommendations and guide users through tailored learning journeys represents a significant leap forward in enhancing user satisfaction and engagement. By analyzing user preferences, past interactions, and search behaviors, AI systems can curate content that resonates with* *individual users, thus making the search process more aligned with personal interests and learning goals. This bespoke approach democratizes access to information by catering to users with diverse digital literacies, ensuring that the technology is inclusive and accessible to all. Indeed, the expected results underscore a critical move towards democratizing access to information, where the ease and enjoyment of the search process are emphasized across user demographics. By breaking down barriers to digital literacy and making the search experience more accessible and pleasurable, this new paradigm has the potential to level the playing field, enabling users from varied backgrounds to explore, learn, and grow in the digital age.*

Research limitations. *The core limitation of this study stems from its concentrated examination of a young demographic, specifically individuals aged between 13 and 18 years. While this group represents a critical segment of the digital user base, known for its adaptability and engagement with emerging technologies, it does not encapsulate the full spectrum of experiences, behaviors, and expectations prevalent across the broader population. The unique digital literacy levels, cognitive development stages, and social contexts of this age group may influence their interactions with and perceptions of AI-driven conversational interfaces in ways that are not entirely representative of other demographic segments. Consequently, the findings of this study, while valuable, offer a perspective that could be limited in its applicability to the wider population, potentially overlooking the varied needs, limitations, and opportunities that other age groups face in relation to technology adoption and interface design.*

Managerial implications. *The advent of AI-driven conversational interfaces marks a pivotal shift in the digital landscape, presenting both challenges and opportunities for organizations across various industries. This evolution underscores the need for a strategic reassessment of user interface design, where the focus transitions from traditional, static models to dynamic, interactive, and personalized experiences. Managers and decision-makers are tasked with recognizing the potential of AI to revolutionize customer interactions, streamline operations, and enhance the overall user experience. This requires a proactive approach to integrating AI technologies, ensuring that they align with organizational goals and user expectations. Organizations are encouraged to make substantial investments in AI technologies, recognizing their potential to offer significant competitive advantages. This involves not only financial investments in acquiring AI tools and platforms but also investing in the development of in-house AI capabilities. Building a robust AI infrastructure necessitates training and hiring skilled personnel, including data scientists, AI specialists, and UX designers who can harness the power of AI to create innovative user interfaces. Such investments also extend to ongoing research and development activities, ensuring that AI applications remain cutting-edge and responsive to evolving user needs. Moreover, in the era of AI-driven conversational interfaces, organizations must strive to create digital experiences that are intuitive, accessible, and engaging. This involves designing interfaces that can understand and anticipate user needs, provide personalized responses, and facilitate a seamless interaction. Ensuring accessibility is also critical, as digital solutions must cater to a diverse user base, including individuals with varying levels of digital literacy and those with disabilities. By focusing on these aspects, organizations can enhance the effectiveness of their digital interfaces, fostering positive user experiences that drive engagement, satisfaction, and loyalty.*

Originality of the paper. *This paper carves a unique niche within the academic and practical discourse on the intersection of Artificial Intelligence (AI) and user interface design. It extends beyond the conventional analysis of AI's technical capabilities to explore its transformative potential in making technology more democratic and accessible. By focusing on the nuanced ways AI can enhance user interface design to engage next-generation users effectively, this study offers fresh insights into creating digital environments that are not only technologically advanced but also universally accessible and inclusive. This dual emphasis on innovation and accessibility distinguishes the paper within the broader realm of technology management and human-computer interaction research. Moreover, while numerous studies have explored the technical aspects of AI and its applications in various domains, there remains a dearth of comprehensive analysis on how AI-driven advancements in user interface design can democratize access to technology. By elucidating the ways in which AI can make digital tools more intuitive, personalized, and engaging, this paper illuminates a path forward for leveraging technology to bridge digital divides. It underscores the importance of a user-centered approach in the evolution of digital interfaces, advocating for the development of systems that cater to a wide spectrum of user needs and abilities.*

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General management

Blockchain Waste Management: A Systematic Literature Review for the Public Administration

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Abstract

This research contributes to the studies on public service innovation and the New Public Governance theory. The results are based on a systematic literature review that was carried out to characterize and critically evaluate the published literature on blockchain waste management until 2024. A keyword search was first performed by using IEEE Xplore, Google Scholar, Science Direct, Scopus, and Web of Science. After removing the papers that were not closely related to the topic, 120 articles were retained for an in-depth review. The research highlights how blockchain technology applications in waste management have the potential to change the current organizational patterns and support the public service processes in assuring cleanliness and healthy environments for communities. Among multiple new digital technologies, the characteristics of blockchain have made it promising to transform many activities related to public service provision, such as waste management. Public Administrations are found to benefit from the application of blockchain technology through improvements in processes efficacy and traceability, while regulatory uncertainty and questions around scalability represent major costs and risks for them. This systematic literature review makes several contributions. Firstly, providing insights for interpreting some emerging applications of blockchain in the field of waste management and clarifying the research paths in the context of blockchain, digitalised waste management, and circular economy. Secondly, identifying the main research topics and research methods, it enables researchers to identify which areas are yet to be explored and shows those that have already been discussed by extent in the literature. The need for more in-depth research has emerged to have a full understanding of the situations in which blockchain technology is beneficial.

Keywords: *waste management; blockchain; systematic literature review*

Framing of the research. *Today's resource production and waste generation is causing unprecedented environmental degradation, climate change, and pollution. Among the public services that are impacting sustainable development, waste management plays a fundamental role (Rakesh et al., 2021). The importance of waste management in sustainable development is stated by the UN's Sustainable Development Goals, goal 11, i.e., "Sustainable Cities and Communities" in target 11.6 aims at reducing the adverse per-capita environmental impact of cities paying attention to municipal and other waste management by 2030 (The Global Goals). The World Bank describes waste management as the collection of solid waste from the point of generation to the point of treatment or disposal. Yet a more comprehensive definition of waste management in line with the sustainable development challenge states that waste management is the ability to deal with waste generated and eliminate its destructive effects on the environment, economy, and human health (Ishtiaq et al., 2018). There are two major concerns regarding waste management systems: one related to public sector reform legislation, and the other to sustainability in the urban context (Mendes et al., 2012). Municipal solid waste management is an area where improvements are needed since most household wastes comprise biodegradable components, which, when buried, contribute to soil, surface, and groundwater pollution and greenhouse gas emissions (Vambol et al., 2023).*

The Public Administration (PA) has the responsibility of making strategic decisions that affect the daily health, productivity, and cleanliness of communities due to global consumption patterns and waste management (Kaza et al., World Bank Group, 2018). The New Public Governance (NPG) seems to be the conceptual tool that best reflects the reality of the working lives of public managers. The NPG states that public service delivery requires the governance of sophisticated public service systems where innovation plays an important role (Osborne S. P., 2010). In fact, innovation is seen as a means through which to achieve service efficiency and effectiveness and the base for the structuring of a sustainable business model of PSOs (Brown, Osborne, 2015). Through an innovation-oriented approach, smarter and

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more sustainable cities are growing where the public administration (PA) agenda considers sustainability as a key success factor (Gnan et al., 2013, Homsy and Warner, 2015, Deslatte et al., 2017, Rodrigues et al., 2018). The alignment between municipal waste management policies and strategies and its operations is fundamental to build a strategic vision based on sustainable development that guides performance results (Sukholthaman et al., 2017; Wilson et al., 2015; Mendes et al., 2012; Rodrigues et al., 2018). Sustainability involves three systems: environmental, economic, and political/social systems. The challenge of governance, and thus of PA, is to sustain each system on its own while maintaining an appropriate balance among them (Fiorino, 2020). The PA has to deal with the expense of urban waste management and the limited resources, the capacity of planning, contract management, and operational monitoring. Waste management operations must contend funding with other priorities for communities such as clean water, education, and healthcare when nearly 4 percent of the budgets in high-income countries are already dedicated to waste management – the budget rises to 20 percent in low-income countries. Only with accurate data, it is possible to design systems with the right number of vehicles, establish efficient routes, set targets, and track progress (Kaza et al., 2018; World Bank Group, 2018). Studies show how blockchain technology offers new means to assure transparency, prevent fraud and establish trust in the public sector (Rizal et al., 2018). Blockchain technology is a peer-to-peer distributed network that contains the complete record of transactional ledgers in an immutable and transparent manner (Chen et al., 2018; Shaik et al., 2021). It is defined as "a technology for sustainability transformation of the linear economic paradigm"*: it can favor the adoption of circular practices thanks to a double integration that identifies those responsible for the entire lifecycle of waste flows, with a reduction in management costs and control time (Centobelli et al., 2021; Krajnakova et al., 2019; Centobelli et al., 2021; Bockel et al., 2021). Blockchain technology and the circular economy are the two emerging concepts that will revolutionize lives in the upcoming decades as blockchain provides transparent information and reliability to the circular economy system (Khadke et al., 2021). However, blockchain adoption and use in the context of waste management is only partially explored in academic research.*

Purpose of the paper. *This article aims to explore the current research topics and challenges regarding blockchain adoption in waste management and share future directions for PAs. The research might serve as an overview of the current state-of-art of blockchain technology solutions leading to the obtainment of the United Nations Sustainable Development Goals (SDGs).*

To pursue this aim, the following research questions have been formulated:

RQ1: What are the main characteristics of literature regarding blockchain in waste management?

RQ2: What are the main applications of blockchain in waste management analysed by current literature?

RQ3: What are the challenges that the PA may face in introducing blockchain technology in waste management?

Methodology. *The authors have chosen to use a systematic literature review which enables the identification of the main literature gaps and the future research fields that could still be developed (Tranfield et al., 2003). NVivo12 facilitated the organization and extraction of information required for a systematic literature review. The process included the creation of a database of the records, their codification, and analysis. NVivo is a software package built to analyze qualitative and non-structured data. Different classifications have been created to organize the data extraction process. Firstly, each record was catalogued regarding its general characteristics, including title, author, year, type of publication, method, journal, and policy sector addressed. Next, a coding scheme has been created including criteria such as the focus of the papers, the geographic area of the authors, and the research method used (Tab. 1).*

Tab. 1 *Categorization criteria*

A: Research Focus	*B: Geographic Area*
A1. Solid waste management	B1. Europe
A2. E-waste management	B2. North America
A3. Water waste management	B3. South and Central America
A4. Plastic waste management	B4. Asia
A5. Other	B5. Oceania
	B6. Africa
	B7. Mixed
C: Research Methods	
C1. Qualitative method	
C2. Quantitative method	
C3. Case study	
C4. Design Science Research	
C5. Literature review	
C6. Other	

Results.

RQ1: What are the main characteristics of literature regarding blockchain in waste management?

Although the authors did not choose a specific time frame while creating the article database, the presence of articles focusing on blockchain in waste management is found mainly from 2018 onwards. The number of papers and the year of publications show how the topic is still relatively new in literature, which indicates that several research gaps are yet to *be addressed to fully comprehend the impact of blockchain technology on waste management and consequentially the PA organization and strategies. The papers analysed in the review process result being written mostly by authors from the Asian geographical area. As for the research methodologies, the DSR method has been most applied.*

During the review process, solid waste management resulted as the most frequently identified research topic which is fundamental to address the governance process of municipalities: it is a key administrative unit for managing urban waste and delivering an eco-friendly environment to the citizens residing in urban areas (Akram et al., 2021).

The main applications of blockchain in waste management analysed in literature are identified in data sharing and management reward-based systems, fraud prevention, and real-time waste collection (Ratnasabapathy et al., 2019; Pellegrini et al., 2020; Taylor et al., 2020; Akram et al., 2021).

RQ2: What are the main applications of blockchain in waste management analysed by current literature?

Blockchain technology is identified as the solution for fraud prevention incentivizing individuals to correct disposal of waste, but also for data sharing and management, to digitalize documentation of activities such as waste generation, waste collection, and recycling (Salmon et al., 2021; Akram et al., 2021). Blockchain technology is also applied to implement the digitalized documentation of activities such as waste generation, waste collection, and recycling (Akram et al., 2021). The presence of an electronic database and the electronic sharing of information relating to waste makes it easier to record all data relating to the life cycle of materials and products, improving the related control activities, and increasing collaboration among them (Pellegrini et al., 2020). Due to the traceability of data written and shared on blockchains, recyclers can keep track of the waste generated as it moves through the various chains. Consumers can also use the public ledger information to make more informed product purchasing decisions (Khadke et al., 2021). Furthermore, blockchain data cannot be edited, it is therefore important to have robust protocols for recording transactions, such as automating the process using complementary technologies or requiring digital signatures from all parties involved in a transaction (Taylor et al. 2020).

Reward-based systems motivate individuals in the correct disposal of waste (Zhang 2022; França et al., 2021, Akram et al., 2021; Sen Gupta et al., 2021). An organization employing smart waste management and a reward-based system can allow the recycling of waste and promote sustainability. From a government perspective, monetary government services and products can be allowed to be paid off using the tokens, thus increasing market demand for the tokens, which in turn motivates users for waste segregation (Sen Gupta et al., 2021).

A possible application of Ethereum's Blockchain digital architecture has been implemented in a small municipality in the State of Sao Paulo, Brazil (França et al., 2021). Crypto-coins and security support are applied through Ethereum's Blockchain to replace a paper-based system where low-income households get the so-called Green Coins in exchange for their selected solid waste which is used by local registered traders. The aim was to incentivize citizens to a correct solid waste collection process through the possibility of buying assets with the Green Coins and for the Municipality to sell solid waste to recycling companies. The use of social cryptocurrencies supported by blockchain innovates the standards of negotiation between collectors and local commerce, as well as the reliability and trustworthiness of the monetary transactions bringing benefits to public administrations. The interest for a social-currency system is growing and the benefit is identified in a different view of the collection and disposal of waste which may be viewed as economically worthwhile (Zhang, 2022).

Furthermore, automatic reward systems for the disposal of waste in smart bins have been proposed (Akram et al., 2021). Smart bins are bins where a sensor node can communicate data to a cloud server via a gateway. Interoperability is the key to making the system work. IoT and a blockchain network are linked for a real-time implementation where the IoT devices of the bins monitor data in real-time and the weight of the bins creates new transactions in the blockchain network.

Lastly, real-time collection of waste from bins once they are full and real-time disposal of waste from vehicle to disposal area if the vehicle container is full are of research interest. Real-time decision-making is a priority in a smart and sustainable city (Gupta et al., 2019; Gupta et al., 2021).

RQ3: What are the challenges that the PA may face in introducing blockchain technology in waste management?

Blockchain waste management represents an advantage for the PA yet, the assumption that all entities may cooperate and agree to be part of a common blockchain system may be a limit to its fruitful application. Furthermore, a significant challenge for blockchain systems is implementing governance and determining a process for maintenance and upgrades (Scott et al., 2021). Among the possible challenges that the PA might find in the attempt to implement blockchain technology to waste management in their organizational and strategic processes the lack of education and training of those actively using the applications and the lack of regulations are two of the most frequently identified (Ongena et al., 2018; Pucihar et al., 2018; Zhang et al., 2022; Torkayesh et al., 2021; Khadke et al., 2021). Nonetheless, blockchain data cannot be edited, incorrect additions cannot easily be fixed, and the ownership of data must be clearly defined from the beginning. The data entered on the blockchain must be correct. The type of responsibility and whether it transfers with ownership may be set out in laws and policies, but gray areas exist (Taylor et al., 2020). Yet 20% of the barriers to the application of blockchains are due to technical reasons, another 80% are due to current business processes, modes, and management systems (Mori 2016; Song et al., 2022). Therefore, the main challenge in applying blockchain to waste management is the current business processes and the lack of institutional innovation or, even more importantly, the presence of Internet around waste facilities to transform the required data (Song et al., 2022). Yet there is a need for *more empirical research. A continuity of research should involve testing systems in real operating environments, and developing the studies based on Science Design Research (França et al., 2021).*

Research limitations. *The main limitations of this review are determined by the very infancy of the literature on blockchain in public services. One of the shortcomings of the literature is the scarce number of empirical analyses on blockchain in waste management. Secondly, even though the search and screening process has been carried out in detail including multiple datasets, there is a possibility that some high-quality work has been left out. Finally, this article does not cover the technical and computational aspects of blockchain technology. Further research is needed to understand what the necessary steps for the PA are holistically considering the processes needed to implement blockchain waste management.*

Managerial implications. *The results of this systematic literature review show how blockchain technology has the potential to facilitate sustainable managerial processes for PAs. Nonetheless, blockchain technology can facilitate the incorporation of good governance characteristics: participation, transparency, responsiveness, effectiveness and efficiency, and accountability (Steenmans et al., 2021). Blockchain can completely change the way people manage environmental resources and help promote sustainable development (Herweijer et al., 2018). Blockchain is also a tool to incentivize individuals to follow the correct process in the disposal of waste through certified reward systems using tokens and social cryptocurrencies. Overall, the implementation of smart contracts and IoT brings government agencies and stakeholders on the same blockchain platform improving monitoring and transparency in the waste management processes (Kassou et al., 2021). All the aforementioned are blockchain applications that have the potential of impacting positively both the organizational and managerial flow of activities and the sustainable development of cities and communities. Blockchain can favor the adoption of circular practices thanks to a double integration that identifies those responsible for the entire lifecycle of waste flows, with a reduction in management costs and control time (Centobelli et al., 2021; Krajnakova et al., 2019).*

Originality of the paper. *Integrated with various digital technologies, blockchain holds the potential to address the limitations of traditional waste management systems and introduce novel business models beneficial to both society and the environment (Lamichhane, 2017). This paper stands out from previous reviews by offering an updated examination of recent literature and a fresh analytical perspective to study the advancement and implementation of blockchain technology. Its primary contributions lie in providing a valuable resource for waste management researchers, industry professionals, and policymakers through the consolidation of knowledge and practices in this field, updating the overview with recent findings, and presenting future research directions alongside discussions on challenges and opportunities. The paper also delves into summarizing and analyzing pertinent challenges and opportunities concerning the application of blockchain in waste management.*

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Blockchain Waste Management: are Italian managers ready?

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Abstract

This study contributes to the investigation of blockchain technology applications for waste management. The research is focused on the sustainability of small municipalities through new digital tools since, according to the United Nations Sustainability Goals, the local communities are considered the starting point for sustainability practices. For this purpose, the Italian case is studied as one of the top countries in terms of the number of small municipalities which represent about 60% of the total. The TAM2 model has been applied to qualify the acceptance of blockchain technology among managers of the Public Utilities and private enterprises responsible for waste management in small municipalities in Italy. The results show how the offering of services based on blockchain technology is still partially unknown. There is a need for training not only for the managers to develop the necessary skills to benefit from the blockchain platforms but most importantly for the overall knowledge of the characteristics and the possibilities of new value creation in waste management services. The article contributes to theoretical studies on blockchain for public services and aims at offering a new background for the formulation of national policies for the management of this technology. Nonetheless, it offers a managerial contribution by analyzing data relating to the management of blockchain technology in the waste management sector.

Key words: *Waste Management; Blockchain; TAM2; Italy*

Framing of the research. *Waste management is a critical element of bioeconomy, allowing the natural environment to be kept clean, combined with the use of recycled materials, thus bringing economic benefits (Vambol et al., 2023).*

The Italian waste management policies have been developed based on the European Union's policy framework (European Green Deal - Directive 2008/98/EC). The sustainable waste management processes are based on the measures of the National Waste Management Programme (PNGR) and the National Recovery and Resilience Programme (PNRR). The PNGR is the policy framework designed to guide public policies and incentivize private initiatives promoting sustainable and circular economy practices that can benefit society, economy, and the environment. It is one of the core elements of the Italian National Strategy for the Circular Economy. Similarly, the PNRR has included among its missions the improvement of waste management as a fundamental tool for the implementation of the circular economy, by strengthening separate waste collection infrastructures, modernising and developing new waste treatment plants, and bridging the gap between regions to achieve the recycling targets set by European legislation. The local authorities are responsible for waste collection and disposal. These activities are performed in-house or outsourced to paid waste management contractors and/or licensed private waste management companies. Article 182-bis of Legislative Decree No 152/2006 promotes the municipalities with self-sufficiency in the disposal of non-hazardous urban waste and their treatment waste through the creation of an integrated plant network in the optimal territorial area. The heterogeneity of solid waste composition and different collection and management regimes make the circular economy process in waste management difficult.

The main pain point in the waste streams' analysis is their movement to extra-regional destinations which makes it particularly complicated to follow their path from production to destination. Article 7 of Legislative Decree 36/2003, transposing Directive 99/31/EC and subsequent amendments, provides that the waste may only be landfilled after treatment and in line with these provisions. Mechanical biological treatment is commonly employed as a preliminary step before landfilling or incineration, aiming to enhance the waste's biological stability by reducing moisture and volume. Municipal waste sent to intermediate forms of mechanical biological treatment before a destination of recovery or disposal formed the 30.1% of the municipal waste produced in 2022.

In many cases, mechanical biological treatment plants are located on the same site as landfills or incinerators, as part of a treatment platform. Moreover, both the mechanical biological treatment plant and the treatment plant for the

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organic fraction of the separated waste collection are frequently located on the same site. According to ISPRA (2023) the landfill waste disposal must be halved in the next 15 years (-10% by 2035) the percentage of waste to be sent to material recovery operations will have to be significantly increased to ensure the 60% recycling by 2030 and 65% by 2035.

However, examining the data within a specific region alone can often lead to misinterpretation. This is because waste generated by mechanical biological treatment plants, categorized under Chapter 19 of the European waste list, is often either incinerated, sent to landfills, or processed in facilities located outside of the region. The Italian region Molise is an example where a significant portion (60,6%) of incinerated CSS originates from other regions.

The main difficulties in waste management are related to the impossibility of safely and transparently tracing the path from collection to disposal of waste (Gopalkrishnan et al., 2019). The PNRR program envisages the establishment of a nationwide monitoring system to address issues of illegal landfills and facilitate the achievement of sustainable development goals.

In today's digital era the development of new technologies such as blockchain, artificial intelligence (AI), Internet of Things (IoT) or Cloud Computing is impacting sustainable development practices (Ibáñez-Forés et al., 2014; Jasiulewicz-Kaczmarek & Gola, 2019). Among the aforementioned, blockchain technology has received increasing attention from academia and practitioners due to the numerous benefits for sustainability such as cost optimization, transparency, data verifiability, and facilitation of collaboration between organizations (Sarkis et al., 2012; Morkunas et al., 2019; Figueiredo et al., 2022; Park and Li, 2021; Pizzi et al., 2022; Rejeb and Rejeb, 2020; Pizzi et al., 2022b). The adoption of such technology improves the performances in various areas contributing to sustainable development practices monitoring the processes and facilitating their reporting (Saberi et al., 2019). The presence of a digital database and the sharing of information in a transparent, verifiable, and secure manner is favorable for waste management by putting circular economy principles into practice through the traceability of the entire life cycle of materials and products (Pellegrini et al., 2020; Akram et al., 2021; Baralla et al., 2023; França et al., 2020; Gopalakrishnan et al., 2021; Steenmans et al., 2021; Taylor et al., 2020). Furthermore, systems based on rewards through complementary currencies are used to promote good waste disposal practices sustainably (Zhang, 2018; França et al., 2021; Ahram et al., 2021; Gupta et al., 2021).

Blockchain technology is seen as a means of circular economy by tracking waste until it is reused in new markets (Taylor et al. 2020). Due to the presence of a digital database and the sharing of waste information, blockchain is the tool for recording material and product lifecycle data, improving control activities and coordination capabilities (Pellegrini et al., 2020). In other cases, reward-based systems motivate users to proper waste disposal by promoting sustainable practices (Zhang 2022; França et al., 2021; Akram et al., 2021; Gupta et al., 2021). The use case presented by França et al. (2021) is a relevant example of the possible use of blockchain technology in solid waste management. The article presents the project for the application of Ethereum's blockchain digital architecture in a small municipality in the state of São Paulo, Brazil. The case proposes the introduction of complementary currencies using the Ethereum blockchain in a small municipality in the State of São Paulo. The proper disposal of solid waste by users is rewarded through so-called 'Green Coins' that can later be used to purchase products at participating local shops. The aim is to incentivise citizens for proper solid waste collection through the possibility of purchasing goods with "Green Coins" and for the municipality to sell solid waste to companies responsible for its recycling. Another incentive use case is presented by Akram et al. (2021) with an automatic reward system for individuals for disposing of waste in smart bins. Smart bins are containers in which a sensor node transmits data to a cloud server via a gateway: interoperability is the key to making such a system work. The IoT and a blockchain network are connected for a real-time implementation in which the IoT devices in the containers monitor the data in real-time and the weight of the containers creates new transactions in the blockchain network. Full bins are emptied, and disposal occurs in real-time at the moment the vehicle is full (Paturi et al., 2021; Gupta et al., 2021).

Considering the several benefits that blockchain technology brings in responding to the needs stated by the European and Italian policies, there is still a lack of studies regarding the following research question: "What are the main factors influencing the perceived ease of use of blockchain technology in waste management in Italy?".

Purpose of the paper. *The following research aims to investigate the factors influencing the perceived usefulness of blockchain technology when applied to waste management in small Italian municipalities. In fact, the 2030 Agenda with its Goal 11 "Sustainable cities and human settlements" focuses on the development of urban areas yet suggests that the individual local communities are the first areas to tackle to achieve global sustainability goals. In particular, the Italian case is analyzed as it is one of the largest European countries in terms of the number of municipalities, where approximately 5.498 of them are small municipalities (Istat, March 2022).*

Methodology. *In order to detect perceptions regarding blockchain technology in waste management in small Italian municipalities, the TAM2 model has been applied. TAM2 is one of the models that best captures the degree of acceptance of the use of this technology (Taherdoost, 2022).*

The first step of the study identified the variables that could determine the adoption or rejection of the technology, taking as reference the variables proposed by Davis and Venkatesh (2000): perceived usefulness (PU) and perceived ease of use (PEOU), subjective norms (SN), voluntariness (V), image (IM), work relevance (JR), output quality (OQ), demonstrability of the result (RD), with the addition of transparency (TR), a variable representative of the blockchain attribute. In the second phase, the sample under examination was identified.

Out of a total of 5,535 small municipalities in Italy, the size of the significant sample was found to be 360. Subsequently, a two-tiered stratification was used: in the first included the municipalities belonging to inland areas; secondly the research considered a fundamental requirement underlying the potential of blockchain application: the *access to a broadband network structure (Kaushik et al., 2021). Once the stratification was completed, the municipalities under study were chosen through a simple random selection. Subsequently, the waste management companies of the municipalities selected for the survey were identified. The search was carried out through the institutional website of the municipalities, the website trasparenzatari.it (directly connected to the ARERA database), and through a telephone contact. The final number of companies receiving the questionnaire was 173.*

Data was collected through a questionnaire via the EuSurvey platform. The questionnaire contained an introductory description of Blockchain technology to assure that all the respondents had the basic knowledge of the proposed topic. For each of the statements relating to the identified characteristics, the respondent was asked to rate them according to a 4-level Likert scale from "Strongly disagree" to "Strongly agree". The collected data has been analysed through a linear regression based on the following hypotheses:

H1: Perceived ease of use positively and directly influences perceived usefulness in the adoption of blockchain technology.

H2: Subjective norms positively and directly influence perceived usefulness in the adoption of blockchain technology.

H3: Voluntariness positively and directly influences perceived usefulness in the adoption of blockchain technology.

H4: Image positively and directly influences perceived usefulness in the adoption of blockchain technology.

H5: Work relevance positively and directly influences perceived usefulness in the adoption of blockchain technology.

H6: the quality of the output positively and directly influences the perceived usefulness in the adoption of Blockchain technology.

H7: The demonstrability of the outcome positively and directly influences the perceived usefulness in the adoption of blockchain technology.

H8: Transparency positively and directly influences the perceived usefulness in the adoption of Blockchain technology.

Results. *The results of this preliminary study contribute to the existing literature by shedding light on the perceived usefulness of blockchain technology in waste management processes by managers. The selected sample is representative of small municipalities and municipalities in inland areas in Italy: those are small communities that through the means of digital technologies can assure sustainable development guaranteeing the well-being of its inhabitants and the overall society. The implementation of blockchain technology in these areas is challenging since, according to a preliminary analysis, there is a low level of digital literacy that places Italy in fourth-last place at the European level. This finding is confirmed in the analysis carried out where blockchain is not recognized as an easily usable technology that can add value to one's work, in the eyes of the respondents. This view is further reinforced by the idea that blockchain technology does not bring additional value to one's work in the waste management sector. There is a need to raise awareness of the potential of blockchain technology among staff members and managers through digital training sessions.*

Additionally, the ease of access to a broadband network is perceived as a factor that positively influences the propensity to consider integrating blockchain technology into existing business processes, due to the possibility of more easily creating an ecosystem in contact with all actors in the value chain.

Lastly, the analysis of the attribute of voluntariness shows that the choice to adopt blockchain technology is already influenced by the willingness to innovate processes and stay abreast of today's digital age. In essence, the choice to adopt this technology does not seem to be a top-down decision but rather is dictated by the willingness of companies to adapt to the broader context of sustainable development through new digital technologies.

Research limitations. *The main research limitation is due to the small number of respondents, a larger number of data might give further and more accountable information about the blockchain technology acceptance in waste management in the small Italian villages.* The preliminary results of this research will be further investigated to expand the collection and analysis of data on the Italian territory. Future studies may apply different data collection methodologies through interviews and focus groups to deepen the analysis. Furthermore, the analysis may be extended geographically by detecting differences in the approach to blockchain technology in different areas.

Managerial implications. *The relevance of blockchain technology in the waste management sector is supported by several studies which number is constantly growing. This analysis offers the necessary information to managers who need the tools to implement blockchain technology to guide them towards the necessary steps needed to benefit from the increased positive perception of blockchain and its application to better comply with the new European and national policies.*

Originality of the paper. *This paper offers a new perspective on blockchain technology acceptance starting from the small Italian municipalities that need to preserve their cultural and natural heritage in compliance with the norms on waste management.*

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Creating a Blockchain Governance framework for Circular Economy: Preliminary results

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Abstract

Circular Economy principles applied to delivering more sustainable services have the potential to improve efficiency and have a positive impact on the well-being of citizens, their collective and individual behavior and on the overall sustainability of society. Although several research studies are focusing on the positive impact of blockchain technology on circular economy practices, there is a gap in the knowledge on the enabling blockchain governance frameworks. The governance of a blockchain project is crucial for its sustainability as it enables stakeholders to discuss and make decisions on how the blockchain should evolve sustainably. The research aims at contributing to the definition of the main features of a blockchain governance framework for circular economy through a cross-analysis of the existing literature regarding blockchain governance frameworks and blockchain circular economy application requirements. The blockchain governance framework for circular economy is demonstrated by the application of a case study. The research results might have a meaningful impact on the operating environment of the public sector which has undergone a fundamental shift towards a more competitive nature with an increasing need for innovative service offerings.

Key words: *blockchain; blockchain governance; circular economy; public service*

Framing of the research. *CE is a new business model that shifts from the conventional "make, use, dispose" approach and aims to reduce waste, maximise resource efficiency and realise harmony between the economy, environment, and society (Rejeb and Appolloni, 2022). CE principles applied to delivering innovatively more sustainable public services such as municipal waste management, public transport, public urban spaces, and heritage buildings have the potential to improve efficiency and have a positive impact on citizens, their collective and individual behavior, their well-being, and on the overall sustainability of society (Klein et al., 2020). Yet, the transition toward a CE is a challenging task that requires the involvement of multiple sectors and stakeholders to tackle several issues regarding increased risk, lack of clear responsibility and accountability (Salmenpera et al., 2021).*

Digital technologies, including blockchain technology, are considered essential tools for CE implementation (Piscicelli, 2023; Basile et al., 2023; Siddharth et al., 2019). Blockchain technology may be defined as an online open-source distributed ledger where transactions between different stakeholders can be recorded and updated simultaneously and in real-time (Iansiti and Lakhani, 2017). As a virtue, blockchain has the potential to create cleaner economic transactional processes and help achieve a balance between the environment, economy, and society (Upadhyay et al., 2021b).

The fields of application for blockchain technology are potentially countless (Swan, 2015). Since the introduction of Bitcoin by Nakamoto (2008), its underlying technology (i.e., blockchain) has evolved: environmental, social, economic, individual, and technological sustainability are some of the goals in which blockchain plays a fundamental role depending on the choice of the most energy-efficient consensus algorithm (Hughes et al., 2019; Schinckus et al., 2020).

However, while the benefits of blockchain technology look promising, the adoption and deployment of blockchain in industries are still facing many technical and non-technical challenges (Al-Jaroodi and Mohamed, 2019). Specifically, the governance of a blockchain project is crucial for its sustainability as it enables stakeholders to discuss and make decisions on how the blockchain should evolve (Filippi and Loveluck, 2016; Garagol and Nilsson, 2018).

In business management literature, blockchain governance (BG) is conceptualized as the process by which individuals and groups with ongoing relationships bargain on how to adapt to changes within the institutional environment (Allen and Berg, 2017; Gruin, 2021). On the other hand, some describe BG as the "placement and enactment of decision rights" (Ziolkowski et al., 2020). For the purpose of this study, we consider BG as "the structures and processes that are designed

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to ensure the development and use of blockchain" (Liu et al., 2023). While the structures are defined by the decentralization level, processes mean the coordination between stakeholders throughout the development lifecycles of different governance objects which must be compliant with legal regulations and ethical responsibilities.

The decentralization nature of blockchain differentiates its governance from existing governance frameworks: the main difference sits in the difficulty in describing the allocation of responsibility, capability, and authority (Liu et al., 2023; Werner and Zarnekow, 2020). This study answers to the need for a suitable blockchain technology governance framework investigating the main characteristics suitable for CE practices.

Purpose of the paper. *Identified the lack of research on blockchain governance for CE, and the lack of tools and artifacts to be used to understand blockchain governance for CE.* This research aims to improve the lack of understanding and tools available on the topic of blockchain governance by designing a conceptual framework that captures the dimension and layers of blockchain governance for CE in order to guide business, regulators, users, and other relevant stakeholders to analyze the governance of blockchains in a structured way. The research results might also have a meaningful impact on the operating environment of the public service delivery which has undergone a fundamental shift towards a more competitive nature with an increasing need for innovative and sustainable service offerings.

Methodology. *To understand how blockchain technology can be beneficial for CE we attempted a categorization of blockchain governance structures identifying the ones suitable for this objective. The following research question has been formulated: "what are the characteristics of blockchain governance structures in CE?".*

A cross-analysis of the existing literature regarding blockchain governance frameworks and blockchain circular economy application requirements has been carried out. The conceptualization of a BG framework for CE is based on the analysis of the existing literature. The method used for this research is based on a systematic literature review (Tranfield, 2003). A systematic review is an effective exploratory methodology for early-stage research on blockchain (Frizzo-Barker et al., 2020). Systematic reviews are a form of meta-analysis designed to collect, investigate, and summarize what is known and what is not known about a "specific practice-related question" (Francis-Smythe et al., 2013; Frizzo-Barker et al., 2020). They bridge the "research-practice gap" (Rousseau, 2006) which is the aim of this study. Title, abstract, and keywords were used to search published journal papers and conference proceedings on three electronic database resources: IEEE, Scopus, and Web of Science. The cross-analysis is based on results regarding blockchain governance and blockchain technology for circular economy. We then identified a case study and analysed the BG characteristics through secondary data following the Yin (1994) case study framework. According to Yin (1994), single cases may be used to confirm or challenge a theory, or to represent a unique or extreme case. Case studies tend to focus on one or two issues that are fundamental to understanding the system being examined (Yin, 1994). In this research the case study protocol is based on documentation, archival records, and participant observation.

Results. *The characteristics of blockchain for the CE concern the need to track the environmental and social circumstances that might cause health, environmental, and safety issues. The reduction of poor synchronization and enhancement of information interaction and trust among participants to the supply chain and improvement of social accountability by supporting coordination between different distributed databases (Zhang et al., 2022; Upadhyay et al. 2021c). Blockchain is also expected to control emission reduction, energy and resource efficiency, and waste reduction respecting the legal compliance (Mendoza et al., 2019; Nunes et al., 2018). The Circularise case study does align with the requirements for blockchain in CE identified in the literature. The Circularise case study describes a circular economy business project. The information collected from the official website and other secondary data such as online interviews with the Business Development and Strategy manager, online articles and the Circularise official website. The information is presented with a descriptive structure. Circularise is a software platform that provides end-to-end traceability and secure data exchange for industrial supply chain through Digital Product Passports. According to Phil Brown, Circularise VP Business Developer and Strategist,* "Companies need to provide information on their supply chain and on the percentage of recycled products and the supply chain actors are able to share sensitive data without risking privacy and confidentiality". *Companies with a private wallet can access the Ethereum network through an interface and a mobile application.* "Circularise system enables manufacturers, suppliers and recyclers in the value chain to share data in a secure way, get an oversight of the whereabouts of products and raw materials, get certifications, and to plan logistics and recycling activities for specific materials. Ultimately, Circularise communication system brings us closer to a more sustainable economic model, the circular economy, one product at a time." *(CES 2019).*

Circularise provides a structure and a dataset. The customer receives the aggregation of data validated by a third party. The data is only available to selected participants to the network. The blockchain network adopted by Circularise is Ethereum. In the Ethereum network, the standards are introduced as Ethereum Improvement proposals (EIPs) which community members discuss through a standard process and the system adapts to the changing environment by forks and changes in the consensus mechanism. Ethereum uses a proof-of-stake-based consensus mechanism that derives its crypto-economic security from a set of rewards and penalties applied to capital locked by stakers. This incentive structure encourages individual stakers to operate honest validators, punishes those who don't, and creates an extremely high cost to attack the network. The miners are rewarded in Ether. In a PoS-based configuration, there is no competition between miners since the protocol implements a random selection in which the probability to be selected is related to the number of cryptocurrencies the miners put at stake. In doing so, PoS system avoids the computational competition between miners since only the selected miner validates the transaction and gets the reward. By operating in that way, the PoS protocol also ensures a low level of electricity consumption while guarantees that mining activities can still be done at an individual level (Schinckus, 2020; Vranken, 2017).

The Ecosystem support program allocates the resources to builder tools and infrastructure. Ethereum aims to achieve equilibrium by adapting a democratic governance model, influence from the benevolent dictator, and a possibility for forks. It comprehends open access rights since joining industry organization groups requires an application process and license fee. The Ethereum Foundation manages some community infrastructure, employs team working on Ethereum software such as testing frameworks, and runs official developer conferences. First, as for the level of decentralization, the application of a public blockchain leaves space for a democratic approach of the stakeholders sharing information across the whole value chain. The Ethereum network guarantees a transparent decision process through a PoS validation protocol which is known for being the best solution to respect sustainability requirements. Furthermore, at an ecosystem-level Ethereum Ecosystem Support Program allocates the resources to builder tools, and infrastructure. Ethereum aims to achieve equilibrium by adapting a democratic governance model, influence from the benevolent dictator, and a possibility for forks assuring accountability and legal compliance. The preliminary results of the study show how in order to assure CE, the blockchain is also bonded to legal compliance, hence why the permissioned public blockchain with a medium level of decentralization suits the purpose. Furthermore, the level of blockchain decentralization improves social accountability by supporting coordination between different distributed databases (Upadhyay et al., 2021). Blockchains can also enhance sustainability practices such as recycling performance by motivating consumers to recycle through rewards in the form of cryptocurrency tokens (Oropallo et al., 2021). Through a transparent decision process, organizations could reduce the transaction hierarchy and overcome the uncertainty of key information, including the quantity, quality, and type of recycled products (Chen et al., 2021). Blockchain technology reduces transaction costs in a circular model by improving performance and communication among the stakeholders and assuring accountability of the single participants.

Research limitations. *This paper represents a preliminary result of a broader study of BG in CE.*

Managerial implications. *The role of public services has been fundamental as regards the creation of modern states and societies since they contribute to territorial consolidation, social cohesion, and political stability. The introduction of CE and innovation such as blockchain is a complex process that presents diverse technological, socioeconomic, legal, and cultural opportunities and barriers. Where businesses and individual end-users should take into account the aspect of governance in their choice for a particular blockchain application or platform, it is also a requisite for regulators and developers to apprehend. In this paper, we analysed the six main characteristics of BG in CE following the framework of six BG principles formulated by Liu et al. (2023). We elucidated how governance is studied in blockchain applications to CE. BG is an ongoing research topic, and there is a need to further develop the study of guidelines and design of its structure to guarantee sustainability and a circular economy. This research contributes to system engineering literature by providing a unique view of blockchain governance for circular economy. Researchers and actors of the blockchain systems are provided with a foundation and shared language to understand and communicate blockchain governance decisions. Moreover, one expert noted that blockchain governance is not going away anytime soon: it is especially important when "something goes wrong".*

Originality of the paper. *To the best of the authors' knowledge, no studies are attempting to design a unique governance framework to assure CE practices through blockchain technology.*

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Social acceptance of Decentralized Renewable Energies in East African rural communities: preliminary evidence from a multiple case study

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Abstract

Africa is facing a severe energy crisis, with over 660 million people lacking access to electricity. Renewable energy (RE), including the decentralized ones, offers a promising solution to achieve universal energy access and promote sustainable development. However, the success of this energy transition depends also on the social acceptance of RE projects by local communities. This research study focuses on analysing the social acceptance of geothermal off-grid power plants in four East African regions: Homa Bay County (Kenya), Era Boru (Ethiopia), Lac Abbè (Djibouti), and Bugarama Valley (Rwanda). The communities involved in this study exhibit diverse livelihood conditions and primary economic activities. The study employs a multiple case study approach, combining the Social Representation Theory with a qualitative analysis of data collected through focus group discussions and interviews with community members and key stakeholders. Preliminary findings show that communities display varying degrees of openness and participation towards the geothermal project, and concerns include potential changes in the use of existing geothermal resources and understanding of the new technology. Community ownership, benefit sharing, and understanding of the technology emerge as key factors for social acceptance. Repeated interaction with researchers and understanding of the communities' precarious living conditions appear to influence their level of acceptance towards RE. Encouragingly, knowledge sharing and peer-to-peer communication within similar communities seem to improve acceptance. This study contributes to a deeper understanding of Social Representation Theory and the dynamics influencing the social acceptance of RE projects in Africa, providing valuable insights for the design and implementation of future initiatives. Managerially, underestimating social acceptance and its cultural underpinnings, especially in culturally distinct regions, can be critical. Further managerial implications will arise from ongoing data analysis. Our analysis faced limitations. Inviting diverse participants to focus groups proved challenging due to cultural factors, like gender roles in some communities. Additionally, historical political dynamics may influence RE acceptance. Time constraints prevented revisiting all sites. We recommend future longitudinal studies on social acceptance and communication's impact on socio-cultural factors.

Key words: *energy access; social acceptance; decentralized renewable energy; social representation theory; Africa; rural communities.*

Framing of the research. *Africa is facing a serious energy supply crisis, leaving more than 660 million people without access (IEA, 2022b), just 570 million in Sub Saharan Africa (Liu, Y., & Bah, Z. (2021). The increasing energy demand in the region, fuelled by population growth forecasts, is a major obstacle to sustainable economic development (Adenle, 2020). Improving energy access in Sub-Saharan Africa has the potential to improve, among the others, healthcare, life expectancy, education, recreation, economic opportunities, and gender equality (Opuku et al., 2021; Musango et al., 2020). The lack of infrastructure and poverty are the main reasons for energy access issues in Africa (IEA, 2022c). Energy poverty remains a pressing challenge, also limiting clean cooking technologies (IEA, 2022). Moreover, energy poverty, in a vicious circle, resulting from poverty and perpetuating poverty, hinders development, and disproportionately impacts rural communities (UN, 2021). Fortunately, Africa boasts vast renewable energy-RE potential, offering a promising path towards a brighter future (Bugaje, 2006). Especially in rural areas of Sub-Saharan Africa, RE is considered as a channel to development and livelihood transformation (Liu & Bah, 2021). According to the IEA's NZE scenario, by 2030, more than half of the population will gain access to full electricity through decentralized solutions like mini-grid and stand-*

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alone systems, with 90% of them using renewable energy sources (IEA, 2022). Decentralized Renewable Energies-DREs present a compelling alternative to grid extension in SSA, simultaneously driving energy access and fostering socio-economic development (Mandelli et al., 2016), especially for rural areas and communities.

DREs, as other power plants, need stakeholder support for their implementation (Enserink et al, 2022). Indeed, stakeholders can influence a project by playing a supporting and/or hindering role. At the same time, stakeholders are influenced by the outcome of REs (Ruggiero et al., 2014). Among the different type of stakeholder support, DREs need acceptance; acceptance is a challenge developing countries too (Hosseini et al., 2018). When dealing with development of RE, social acceptance is insufficiently covered by issues of technology design (Dewin-Right et al., 2017). Social acceptance can be measured also ex-ante, with collecting stakeholders' perception and ensuring a match with expectations (Prosperi et al., 2019). Within social acceptance, the community acceptance dimension refers to the specific acceptance of siting decisions and RE projects by local stakeholders, particularly residents and local authorities (Wüstenhagen et al., 2007). Moreover, communities are central actors in current low-carbon energy transitions (Küpers & Batel, 2023). Low-carbon transition is even important in Sub-Saharan Africa, where rural communities suffering from lack of clean energy access can benefit in terms of social development (Casati et al., 2023). Social - and community - acceptance can bring success for developing community-based projects, particularly when implemented with a bottom-up approach (Velasco-Herrejon and Bauwens, 2020). Acceptance of RE can be favoured by community engagement (Jami and Walsh, 2017). Community engagement can help in developing trust and dialogue for the mutual benefit of all involved (Ryder et al. 2022). In Africa, lack of community engagement has been demonstrated as a possible barrier to the DRE project's durability (Akinyele et al., 2018), such as the practice of using only outsiders to plan and execute local community projects could be a recipe for the failure of the systems (Nuru et al., 2022). Community engagement and social acceptance can be favoured - and studied by scholars - through participatory processes, as previous research has successfully demonstrated (i.e.: Alvial-Palavicino et al., 2011; Dewin-Right et al., 2017; Geekiyanage et al., 2020; Jami and Walsh, 2017; Liu & Bah, 2021;).

Purpose of the paper. *Theory-building research on the social-cultural dimension of acceptance of RE is in its infancy (Jami and Walsh, 2017). Research has shown that different theoretical approaches may only capture limited aspects of how society - and communities - perceives energy technologies (Batel, 2018). They may overlook the contributions of various stakeholders, their expectations and engagements, and the varying manifestations of technologies on different levels (Dewin-Right et al., 2017). Our analysis starts from the community acceptance dimension proposed in the framework by Wüstenhagen et al. (2007), theorizing a holistic approach to social acceptance. The paper by Wüstenhagen et al. (2007) is a ground-breaking in the field of research, not only establishing it as a distinct area of study, but also organizing previous research and outlined a direction for future research on the social acceptance of RE, urging a focus on the relationship between opposition to RE and various socio-political, market, and community factors, rather than relying solely on the NIMBY explanation (Batel, 2020). Moreover, Dewin-Right et al. (2017) call for understanding which socio-cultural aspects shape the public acceptance of RE. In addition, Batel (2020) wishes to further develop, at an empirical level, the research on dynamics of people's responses to RE at local level. Dewin-Right et al. (2017) suggest this must be done through examining the communication, both coming from third parties and among the members of the communities, within focus group discussions with members of communities engaging with or affected by RE. We have answered to these calls for research through the lens of the Social representation theory (Moscovici, 2001; Wagner, 2011). Social representations theory examines the evolution of social knowledge, focusing on the psychological and social processes that shape how individuals and communities interpret and adapt to new ideas or technologies like RE adoption. This theory suggests that understanding these changes occurs at both the individual and societal levels, with communication playing a key role in knowledge construction. Social representation theory helped us in analysing and understanding various socio-cultural aspects that can favour social acceptance, including resistances, ability to understand new technology, effects of local beliefs and behaviours (including religious and cultural one), etc. Power dynamics among actors also influence how information is shared and understood (Dewin-Right et al., 2017). Hence, we have also looked for differences in the ability to accept the technology depend on the nature of the stakeholders. Our Research Questions are: "How do socio-cultural aspects shape the community public acceptance of RE? How do local community dynamics affect people response?"*

Methodology. *Our research employs a multiple case study approach (Stake, 2013; Yin, 2015), with different sites for each case study. We took part of a participatory process for a feasibility study on the design of an off-grid geothermal plant, catering to both direct and indirect uses, across four geographically distinct regions in four different countries in East Africa. The regions/counties/districts involved were Homa Bay County in Kenya, Era Boru in Ethiopia's Afar Region, Lac Abbè in Djibouti, and Bugarama valley in Rwanda. These communities exhibit diverse livelihood conditions and primary economic activities. Homa Bay County in Kenya is community of both farmers and fishers, living in an old volcano site. Geothermal energy is present and is used mainly for religious and healing reasons, as well as recreational. The same similar conditions are present in the Bugarama site in Rwanda, with the difference that the communities live mainly from subsistence agriculture and the cultivation of rice and fruit trees. Era Boru and Lac Abbè are morphologically and geographically distinct, as well as culturally. The two sites are united by the presence of the same community, the Afar. The Afar are separated by the border between Ethiopia and Djibouti but share the same cultural customs. The Afar live mainly by pastoralism and are a semi-nomadic community. The sites of Era Boru and Lac Abbè are in the hottest places on Earth, and the population has developed ways of living that depend on the direct use of geothermal energy as a source of water. Each site presents differences inside. For instance, within Homa Hills, three locations directly participate in geothermal direct utilization, while two locations are neighbouring. While belonging to* *the same linguistic and cultural groups (Luo people), the communities showcase distinct social characteristics. In Homa Hills, for instance, some communities are solely focused on agriculture, whereas others primarily engage in fishing on Lake Victoria.*

Willing to study socio-cultural aspects that can favour social acceptance through the lens of Social Representation Theory, we adopted a qualitative grounded theory approach (Chun Tie et al., 2019). Data collection was done priorly with desk research aiming at understanding the communities' features. Then, we conducted at each site, and within various sub-locations, primary data collection.

Data collection methods included focus group discussions (FGDs) and semi-structured interviews with key stakeholders and community members with an interest in the project. These stakeholders encompassed citizens, public authorities, and representatives from non-governmental organizations (NGOs). Each FGD lasted approximately three hours, while interviews averaged one and a half hours. FGD participants were chosen through a random selection process within the community, ensuring representation of various social categories (e.g., occupation, gender, age, community role, religious leaders, etc.). During the FGDs, a research team of three to four individuals with diverse backgrounds (e.g., economist, anthropologist, sociologist, geologist) was present, accompanied by a simultaneous interpreter and translator. To facilitate comprehensive discussions and capture nuanced perspectives, participants were encouraged to express their opinions in their native language (DhoLuo in Kenya, Kinyarwanda in Rwanda, Afar in Ethiopia and Djibouti). We conducted seven FGDs in Kenya, two each in Rwanda, Ethiopia and Djibouti. Interviews span from a minimum of four to a maximum of fifteen for each site. Primary data collection was done between November 2022 and November 2023. Moreover, we visited one of the sites twice, a year later. This second stage enabled a deeper exploration of socio-cultural aspects and communication, both coming from third parties, considering the presence of external actors. All FGDs and interviews were audio-recorded and transcribed by a native mother tongue for each of the languages, resulting in a significant and paramount volume of transcribed data. Data analysis and coding were performed using a combination of manual techniques and dedicated software (i.e., NVivo) by a team of two researchers working collaboratively.

Results. *The analysis of the results is always ongoing, so only preliminary evidence will be presented below. The communities immediately appeared different both in their willingness to participate in the participatory process and in their acceptance of the geothermal plant. Although they were given many opportunities to design the system and be involved in the subsequent phases, some populations immediately showed a bit of reluctance towards the intervention. Others showed concerns regarding the possibility that this plant could change the use that was already being made of the geothermal resource. Some populations, however, have shown interest and openness to possible substantial changes in use, as long as benefits were achieved. Some other populations have demonstrated ability to understand new technology, others less so. In both categories, some were willing to participate in various ways. Surely, communities' members knowledge of RE is very different within the community, depending often on the role inside the community and on the background of individuals. For instance, sometimes, have a certain public role (i.e, public officials) can bring members to be more open-minded. This, at the same time, may be caused to the public role effect on expressing opinion in public.*

A theme that emerged is the possible ownership of the power plant by the community, as long as there is sharing of information first. Nevertheless, ownership is not to be understood in the strict sense. Finally, the site that was visited two times gave interesting results on the effects on community acceptance due to multiple interactions, which were also methodologically different from each other. Another research result, which seemed evident to us, depends on the starting condition of the populations. These populations often live in conditions of accentuated poverty. This can make them accept RE at any cost. Finally, we observed how during the discussions, the community knowledge of RE was influenced both from the intervention of third parties (i.e, experts) and from the discussion within the community, with social processes shaping how individuals and communities interpret and adapt to new ideas on geothermal energy. These results confirm what Social representation theory states, with changes in knowledge construction occurring with the key role of communication.

Research limitations. *Although the data collection was very comprehensive, our article is not without limitations. First of all, when we got into the cases, we realized that, although we had tried to invite more actors to participate in the FGDs, this did not happen, also for cultural reasons. For example, some communities, by religion, expect men to make decisions. So, even if women were present in the FGDs, they often did not speak up or seemed embarrassed to counter men's theories. Another limitation, however, depends on how the ethnic group has experienced some national political dynamics in recent decades. This could affect the willingness to accept the RE regardless of their goodness. Finally, it would have been interesting to return to all the sites twice, but this was made impossible due to time and resource constraints. We suggest further research on longitudinal study on social acceptance and the effect of communication on socio-cultural factors.*

Managerial implications. *The first managerial implication of this article is that the issue of social acceptance for DREs in Sub Saharan Africa should not be underestimated. Above all, the socio-cultural factors behind social acceptance must not be underestimated, especially in areas where the populations have very marked cultural characteristics. What seemed positive to us, however, is the impact of knowledge on social acceptance and of two-way communication made by peers, as when members of similar communities from the same nation were invited into the community. Other managerial implications will emerge as the data analysis continues.*

Originality of the paper. *To the best of our knowledge, the field of social acceptance of DREs in Sub Saharan Africa, looked through the lens of Social Representation theory, is quite new in the management literature. Moreover, RE are still underdeveloped in Africa and new projects could take inspiration from the methodology and managerial implications of our article.*

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Sustainable Management of the Photovoltaic Waste Stream: Regional Analysis and Economic and Management Perspectives

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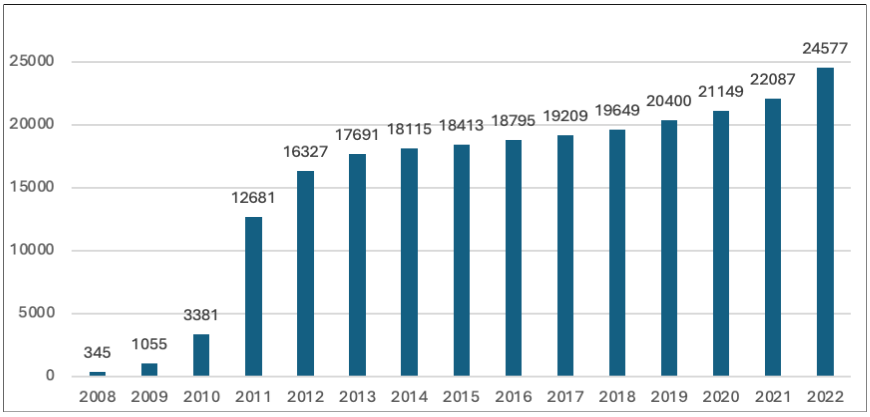
Abstract

Photovoltaic panel utilisation has grown significantly in Italy and globally during the past two decades. This technology's primary benefit is that it converts sunlight into power without emitting greenhouse gases throughout its operation. The lifespan of solar modules is typically restricted to approximately 25 to 30 years. Hence, it is logical to anticipate a further rise in the generation of associated waste in the upcoming years. We suggest a regional approach to estimate the amount of waste that will require disposal, considering the various types of panels now employed in Italy. This method will allow efficient planning of waste management for solar panels. Furthermore, it will encourage the advancement of innovative recycling and material treatment methods, reducing the environmental footprint and guaranteeing sustainable waste management in the future. The methodology will be applied focusing on the installation of solar panels using different technologies (thin film, monocrystalline silicon, and polycrystalline silicon) in Italian regions from 2000 to 2022. A preliminary economic assessment of the materials that can be recovered from photovoltaic panels will be provided.

Key words: *circular economy; EoL PV modules; forecasting; PV waste management; sustainability.*

Framing of the research. *Since the 2000s, there has been a significant global spread of photovoltaic energy as a source of electricity in various regions. This technology is adaptable, widely produced, and has affordable installation costs, making it highly popular among individuals and companies. The global installed capacity increased from 224.215 MW in 2015 to 1.055.030 MW in 2022, marking a growth of almost 350% in a span of 7 years (Source: IRENA, 2023). The total installed capacity in Italy has significantly expanded since 2008 and continues to grow rapidly, as shown in Figure 1.*

Fig. 1: Cumulative PV power installed in Italy (MW)



Source: GSE reports (2008-2022)

The installed capacity in Italy increased by 20.6% during the year 2022, rising from 22.594 MW to 25.094 MW (GSE Report, 2008-2022). Photovoltaic panels are the third most important renewable energy source in terms of installed capacity, following hydropower and wind (IRENA, 2023). Furthermore, solar energy is anticipated to emerge as one of

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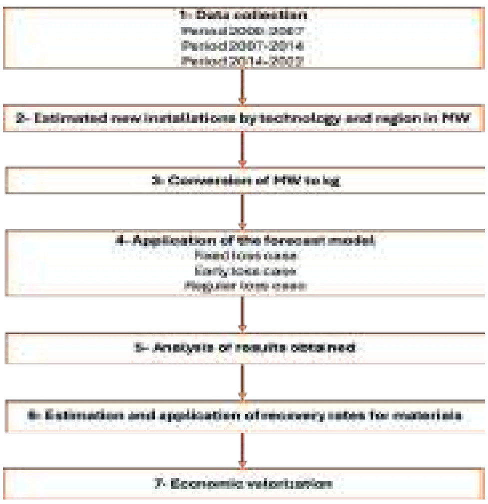
the most prominent forms of renewable energy in the years to come (Romel et al., 2024; Xu et al., 2018). As a result of these installations, there will be a substantial increase in the quantity of waste that is produced by photovoltaic panels in the coming years. Furthermore, despite the ongoing attempts to create new technologies related to renewable energy sources, there is still a void in the literature concerning relevant solutions for the management of photovoltaic modules when they have reached the end of their life cycle (Mahmoudi et al., 2019; Malandrino et al., 2017). Many studies have made an attempt to forecast the waste stream that will be generated by photovoltaic panels in the European and non-European Countries (Czajkowski et al., 2022; Sharma et al., 2023; Tan et al., 2024). used the Weibull function to make the prediction of the waste load in Australia till the year 2059. The life cycle of photovoltaic cells was also taken into consideration. It was necessary to estimate the degree to which photovoltaic technology has penetrated the market in Australia. The authors also recommended the computation of the individual materials that comprise photovoltaic modules. Furthermore, by evaluating the rate of reuse of individual components, they forecasted savings from the recovery of these components for the creation of new modules. This was done from the perspective of a circular economy. Paiano (2015) suggests doing a study that is comparable to this one in Italy; however, the author assumes a fixed period of 25 years as the span of the lifecycle, and the forecast is carried out up until the year 2050. In addition, various photovoltaic panel technologies from the first and second generations are taken into consideration. Calculations were also made in this instance to determine the quantities of waste that were produced and then separated into the various components. Using the Weibull function and taking into account not only the photovoltaic module but also the Balance of System (BOS), which is the collection of all components that are necessary for the proper functioning of photovoltaic modules, Domínguez & Geyer (2017, 2019) carried out a calculation that was comparable in both Mexico and the United States. The authors of this study took into consideration a life cycle that is typically thirty years long. When applying the Weibull function and taking into consideration an average life of thirty years, Romel et al. (2024) made a prediction regarding the quantity of panels that will be available at the end of the life cycle by the year 2045. After then, the outcomes of this particular case were compared with the reports written by IRENA in order to determine how good the results were. Kim & Park (2018), in contrast to the research that were stated earlier, presented not only the waste prediction modelled by the Weibull function but also a defined usable life duration of 25 and 30 years in two different scenarios. As a result, it was possible to do more analyses using data that was comparable. In conclusion, Sharma et al. (2023) not only made a prediction for the quantity of photovoltaic panels that will reach the end of their useful life in India, but they also investigated the issues of reuse, recovery, and disposal, as well as the implementation of policies and strategies that encourage more sustainable waste management.

Purpose of the paper. *The present study is still a work in progress. The aim of this research is to provide a regional method that is capable of addressing the developing difficulty connected to the management of waste resulting from the increasing use of photovoltaic panels. Due to the fact that photovoltaic modules have a limited lifespan, it is expected that there will be a significant increase in the amount of generated waste. As a result, the primary purpose of this research is to develop a method that is both efficient and accurate in determining the quantity and nature of waste that will be generated across the nation, as well as the locations where this waste will be generated. By developing the research for each region of Italy. The study serves as a helpful instrument for businesses operating within the sector to evaluate and plan for the management of solar waste in a sustainable manner. This strategy aims to minimize the environmental impact of photovoltaic waste production by estimating the recoverable amount. Additionally, it aims to promote the advancement of recycling and material treatment through research and development of innovative solutions. This will help to ensure that waste management is sustainable over the long term, with the ultimate goal of achieving a circular economy. In order to give data and practical tools that can be used to guide waste management decisions and policies in the solar energy industry, the approach that has been developed is specifically applied by taking into consideration solar panel installations in Italian regions and in various technologies from 2000 to 2022.*

Methodology. *The proposed methodology is divided into seven steps (Figure 2).*

Fig. 2: Methodology to estimate photovoltaic waste



The first critical data are the total new installations for each year for each technology in each Italian region from 2000 to 2022 (measured in terms of installed power - MW). We consider three types of photovoltaic modules, which represent almost the entirety of the national market, and consist of monocrystalline silicon, polycrystalline silicon and thin film (GSE Report, 2008-2022). The source data (i.e. the new installations for each year broken down by technology and for each region) were obtained from the GSE (Gestore dei Servizi Energetici) reports and from a personal reworking of the data by the Terna database. Due to lack of obtainable data, assumptions were made:

1) 2000 - 2007: data are not available. It was necessary to consider new installations for each region as:

$$New\ installations\ (t) = Total\ installations\ (t) - Total\ installations\ (t-1)$$

The only statistics available for this period are the total installations in Italy at the conclusion of period t. It was therefore necessary to consider the breakdowns of photovoltaic modules as zero over this short period. We took this assumption into account due to the limited number of photovoltaic modules in Italy till 2007. In addition, the percentage distribution of different photovoltaic module technologies within Italian regions was considered constant.

2) 2008 - 2014: data are not available. Data on new installations in Italy are available for each year. To obtain the data on new installations per region, the percentages of installations per technology in the different regions were considered constant, taking 2015 as the reference year.

3) 2015 - 2022: data on new installations are available for each region and for each year.

As a result, in Figure 3 new installed capacity by Italian region for different years are reported, respectively 2012, 2017, 2022.

Fig. 3: New installed capacity by region (MW)

Source: Personal elaboration from data available on GSE Reports 2008-2022

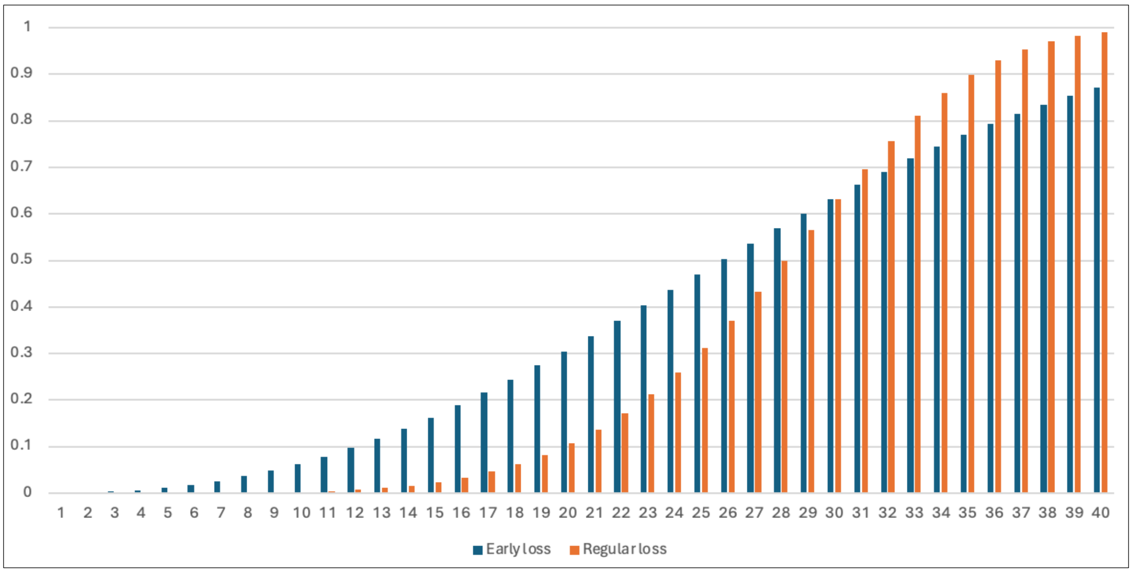
By multiplying the total number of new installations by the percentage of technology used in each region, we obtained the necessary data. The data obtained in MW were converted into Kg of PV modules, obtaining the conversion factor from EPDItaly (Environmental Product Declaration), following the methodology proposed by IRENA (2016) and applied by Mahmoudi et al. (2019) and Paiano (2015). Prediction regarding the generated waste stream was conducted for different scenarios:

- *Fixed loss: considering a useful life of 25 years (Paiano, 2015).*
- *Early loss e Regular Loss: both modelled using Weibull function.*
  The Weibull function is reported as follow:

$$F(t) = 1 - e^{-(\frac{t}{T})^{\alpha}}$$

Where t represents the useful life of the photovoltaic module, T represents the considered average life of 25 years, and α is called the shape factor and is responsible for the shape of the Weibull curve. An α value of 2.4928 was considered for the Early-loss scenario, and a value of 5.3759 for the Regular-loss scenario. (IRENA, 2023; Mahmoudi et al., 2019; Sharma et al., 2023). In Figure 4 probability of loss based on Weibull function is reported.

Fig. 4: Probability of loss based on Weibull function



In Table 1 average lifetime of photovoltaic modules considered in other studies are reported, divided into different regions.

Tab. 1: Values of average lifetime of PV considered in other studies

Region	*Global (IEA, 2016)*	*Mexico (Domínguez & Geyer, 2017)*	*Australia (Mahmoudi et al., 2019)*	*Italy (Paiano, 2015; this study)*	*Europe (Lugo-Laguna et al., 2021)*	*India (Sharma et al., 2023)*
Average lifetime (year)	*30*	*30*	*30*	*25*	*25*	*25*

Data on the composition of the materials making up the photovoltaic modules and their recovery rates will allow us to proceed to the final stages of the study, namely the estimation of recoverable materials and the resulting savings (Domínguez & Geyer, 2017, 2019; Peeters et al., 2017).

Results. *It is important to keep in mind that the current study is still considered to be a work in progress. One of the most important findings, is the precise calculation of the quantity of material that may be recycled or reused from photovoltaic cells that have been discarded. This was done within the framework of the circular economy. This computation method was carried out for each of the locations in Italy as well as for a variety of technologies, taking into consideration the time period spanning from the year 2000 to 2047. This particular time span was selected to be reflective of the typical lifecycle of photovoltaic panels, which is anticipated to be somewhere between 25 and 30 years.*
Taking into consideration the current historical backdrop, we designed an investigation to determine whether components from decommissioned solar panels could be categorised as dangerous or crucial (Lin et al., 2022). It is essential to take this step in order to acquire a comprehensive understanding of the environmental and socio-economic implications of solar waste management, particularly considering the rising issues that are associated with the availability of resources and the safety of materials (Lin et al., 2022). In addition to the quantification of the materials that are recyclable or reusable, a comprehensive economic analysis of these materials will also be carried out. The purpose is to determine the economic value of these materials and, from the point of view of a circular economy, the potential cost savings that the recovery of these materials might entail when it comes to the production of new photovoltaic modules. In addition to evaluating the viability of investing in recycling and reuse processes, this stage is vital for gaining a comprehensive understanding of the economic ramifications of adopting circular economy strategies in the photovoltaic panel industry. We will be able to provide an evaluation of the potential economic value of these materials. In the solar panel business, this gives a strong basis for making informed decisions and developing waste management plans, which in turn contributes to the promotion of responsible and sustainable resource management.

Research limitations. *The presented research may encounter some limitations. Firstly, the collection of detailed data on the installation and distribution of solar panels may be hampered by the lack of comprehensive information, especially regarding the specific technologies used and accurate waste disposal predictions. As presented in the methodology section, some assumptions were made in order to obtain the necessary data for the completion of the study. This might compromise the replicability of the study for other states. In particular, both national and international databases were used, such as Terna, IEA (International Energy Agency), GSE (Gestore dei Servizi Energetici) and IRENA (International Renewable Energy Agency); despite this, the regional market breakdown per technology used was not always detailed and timely, and needed to be adapted. Another aspect to consider is related to the assumptions made about the* *replacement of existing solar panels with new, more efficient technologies over time. Changes in replacement rates could affect waste generation projections. The complexity of photovoltaic waste management is a further challenge, especially if there is no adequate infrastructure for recycling and material treatment. Research may not fully address the practical realities and economic challenges of PV waste management. Environmental and social factors, such as impacts on human health and the environment due to exposure to chemicals during material recycling, would merit further investigation and a dedicated study. Finally, the research conclusions may be specific to the Italian context and may need to be adapted to be applied to other regional or national contexts.*

Managerial implications. *The exponential increase in the use of solar panels over the last 20 years has raised awareness of the importance of managing the technology's life cycle responsibly. When solar panels reach the end of their useful lives, it is essential for businesses and policymakers to make preparations for the management of waste not only during the manufacture and installation phases, but also after the panels have been installed. A strategic approach is required for this planning, which includes not only an accurate assessment of the amounts and types of waste that are generated, but also the creation of new solutions for the recycling and treatment of these wastes. In this context, businesses are being asked to make investments in the research and development of technologies for the recovery and treatment of photovoltaic materials, and they are being asked to achieve this in collaboration with other participants in the industry, governmental organisations, and research institutes. This partnership could be critical in developing sustainable solutions that can adapt to the rapid evolution of technology and environmental legislation.*

This research is designed to provide utility for all parties involved. First and foremost, from the perspective of the businesses, it could be interesting to have a clear understanding of the economic return, that the photovoltaic recovery sector will have in the years to come. In this regard, the originality of the research, which consists of the determination of the amounts and regional position of the waste stream that is generated, is an helpful and all-encompassing instrument for the period of strategic business planning. On the other hand, the management implications of the circular economy in the photovoltaic panel industry necessitate a strategic and coordinated approach at the governmental level (Goe & Gaustad, 2014). In the past, policymakers in Italy have provided incentives for the manufacturing and installation of solar systems in order to encourage the growth of the photovoltaic industry so that it may serve both private and corporate consumers. In recent years, the growing utilisation of this technology has resulted in an immediate requirement to handle the issue of waste generated by photovoltaic cells at the end of their useful lives. To handle this new problem, policymakers must also encourage laws and regulations aimed at recovery and maximising the use of available resources (Goe & Gaustad, 2014). In addition to providing incentives for practices that involve the study and development of technology for recycling, recovery, and treatment of photovoltaic materials, these policies should also provide incentives for manufacturers to use recovered end-of-life materials as inputs (Lin et al., 2022; Zhang et al., 2023). Furthermore, policymakers should support the formation of partnerships between the public and commercial sectors, research institutes, and non-governmental organisations to create new and collaborative solutions for the intelligent management of photovoltaic panel waste. In order to achieve this objective, it is necessary to implement monitoring and control methods in the photovoltaic industry in order to guarantee compliance with environmental requirements and to ensure that waste is managed appropriately.

Originality of the paper. *The originality of this paper lies in the innovative approach proposed to address a growing environmental challenge arising from the expanding use of photovoltaic panels. Although solar technology has provided substantial benefits in the production of clean energy, the research emphasises a frequently underestimated aspect: waste management at the end of the panels' life. As previously mentioned, various studies have been published in recent years to determine the quantity of waste generated by solar modules (Domínguez & Geyer, 2017, 2019; Mahmoudi et al., 2019; Paiano, 2015; Peeters et al., 2017; Santos & Alonso-García, 2018; Sharma et al., 2023). To the best of our knowledge, no one has ever penetrated into the regional context. Instead, our study presents a specialised regional technique for calculating and planning waste management from photovoltaic panels, taking into account the variety of technologies employed and the predicted increase in waste generation. This strategy is innovative because it takes a long-term view on solar waste management, anticipating and minimising potential negative environmental consequences. In particular, the study addresses businesses by providing a useful tool for planning investments to respond to a rising problem in our country, as well as the option to consider an economic return. On the other side, the study addresses policymakers in the same way, encouraging businesses and investors to approach a sensitive and timely problem. As a result, applying the proposed methodology to the specific Italian context makes an important contribution to the political and decision-making context, providing data and concrete tools to help decision makers make decisions about photovoltaic waste management and the promotion of effective environmental policies in the renewable energy sector.*

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