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**Department of Accounting and Information Systems**



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## **Round Table**

Round Table Discussion on the *“Impact of New Technologies and Artificial Intelligence on Education”*

### ***Moderator:***

**Vicky Arnold**, University of Central Florida, USA

### ***Invited Speakers:***

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# Curriculum Development for Accounting Schools in Technology-driven Environment

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## Abstract

Accounting and related disciplines, such as auditing, are fields that are rapidly incorporating new developments in AI. This suggests that the curricula of accounting schools should be modified to integrate data analytics and related emerging technologies in a way that educates future professionals with the profound skills and knowledge needed in today's environment. This paper describes the significance of new technologies and AI tools for undergraduate students and proposes a procedure for restructuring the curriculum of DAIS. Although we recognize the impact of AI tools on today's business and academic environment, we claim that the usage and teaching of these tools should be accompanied by critical thinking, judgment, and interpretation, which are still human-related skills that need to be taught to the students of accounting and business schools. The paper aims to share a framework of standards and processes for updating the curriculum, contributing to the current discussion on the importance of new tools and technologies for the accounting and auditing profession. Several approaches and methods presented in the literature concerning the development of new programs of study are also discussed.

**Keywords:** *AI Research, technology-driven environment, curriculum, auditing data analytics*

# **Organizational commitment and job performance in the era of digital transformation: empirical research in Greek enterprises**

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## **Abstract**

Organizational commitment and job performance are recognized as key factors in enhancing employee performance, especially in the modern era of digital transformation and Industry 4.0, where new challenges are emerging in human resource management. The importance of this issue is particularly significant, as businesses seek strategies to strengthen their employees' commitment with the aim of improving their performance. The purpose of the present study (part of a broader research project) is to investigate employee organizational commitment and job performance through an empirical survey conducted on a sample of 223 employees and business executives from various sectors of the Greek economy. The main objectives of the research are: i) to document and explore the views of Greek employees regarding their organizational commitment and job performance and ii) to examine the impact of employees' demographic characteristics on organizational commitment. Findings indicate that employees' organizational commitment is generally moderate, with affective commitment scoring the lowest, suggesting that employees do not feel a strong emotional attachment to their organization. On the contrary, continuance commitment and normative commitment are at higher levels, indicating that employees remain in the organization more due to a lack of alternative options and less due to personal dedication or a sense of moral obligation. As far as job performance is concerned, results show that it is positively influenced by factors such as payment/salary, promotion opportunities, management/supervision, nature of work, communication inside the organization and fringe/extra benefits. Regarding the impact of demographic characteristics, the results did not show statistically significant differences between men and women in terms of organizational commitment. This research contributes to the understanding of the factors that influence organizational commitment and job performance of Greek employees, offering valuable insights for organizations seeking to improve the working environment and formulate accordingly their human resource strategy.

**Keywords:** *Organizational commitment, job performance, digital transformation, human resource management, research*

# **The impact of emotional intelligence on transformational leadership and team dynamics in promoting innovation. A literature review**

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## **Abstract**

The interplay between emotional intelligence (EI), transformational leadership (TL), organizational climate, team dynamics and innovation is a complex and multifaceted topic that has attracted significant attention in organizational behavior and leadership studies. EI enhances empathy, trust and decision-making, promoting a collaborative environment and plays a critical role in enhancing transformational leadership within innovation teams. TL is characterized by its ability to inspire, promote a vision, create a supportive work environment and motivate employees to go beyond their interests for the collective good, promoting creativity and innovation. The purpose of the research is to map the mechanisms through which EI influences the transformational leader, as well as the dynamics of his team and how these mechanisms lead his organization to innovation. The main research hypotheses are i) whether emotional intelligence contributes to the ability of transformational leaders to inspire their teams for innovative outcomes, ii) whether transformational leaders can leverage EI to create an environment that encourages open communication, idea exchange, and enhances team cohesion in different work settings and iii) whether leaders with high EI can effectively manage change to promote a culture of innovation that promotes knowledge sharing. Based on Webster and Watson three-stage systematic literature review methodology; all relevant primary research studies, published and unpublished, as papers or articles in press, conducted worldwide and written in English, were identified in ScienceDirect, Scopus and Web of Science. For the research, only articles from 2019 to 2025 were selected for further analysis, thus formulating a sample of 155 articles. As organizations continue to navigate, an increasingly complex and competitive landscape, integrating emotional intelligence and transformational leadership will remain a critical factor in achieving sustainable success. These relationships are observed in various sectors, from technology, manufacturing, telecommunications, education, to healthcare. The quality of leader-member exchange mediates the relationship between leadership and innovation, empowering employees to contribute to organizational goals. By leveraging these factors, organizations can create a culture that encourages creativity, collaboration, and innovation. However, the strength of the relationship between management transformational leadership and employee cohesion varies depending on the measurement methods and sources. Meta-analyses suggest a moderate correlation between emotional intelligence and transformational leadership.

**Keywords:** *emotional intelligence, transformational leadership, organizational climate, team dynamics, innovation, literature review*

## **Innovative information and communications technologies for the digital transformation of companies and organizations**

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### **Abstract**

The aim of this study is to explore the role and the importance of innovative information and communications technologies, such as Artificial Intelligence, Augmented Reality, Blockchain, Chatbots and Cloud Computing in the digital transformation of companies and organizations. Our analysis is based on an extensive literature review, concerning the definition of each technology and statistics of its use, the areas that each technology can be applied and the opportunities and challenges of its adoption and use by enterprises. In addition, we examine how these technologies support the transition toward Industry 4.0 and Industry 5.0 paradigms, where smart manufacturing, cyber-physical systems, and human-centric automation reshape production systems and operational models. The integration of such technologies enhances real-time decision-making, predictive maintenance, supply chain optimization, and process automation, all of which are central themes in operations research and industrial engineering. Moreover, for each technology we review selected studies with empirical research about the adoption of each technology, by presenting the theoretical model or framework that was applied (TOE, TAM, DOI etc.), the factors that were examined and the main results-findings of each study. Emphasis is placed on decision-support methodologies and optimization models that can be utilized for the effective deployment and orchestration of these digital tools within productive environments. Our review provides useful insights into researchers and can be the basis for a more detailed study on the adoption and use of the technologies mentioned. Also, it provides managers with a short but complete overview about the main issues concerning these technologies, in order to plan accordingly their strategy and align their digital transformation roadmap with principles of operational excellence and technological innovation.

**Keywords:** *Digital Transformation, Artificial Intelligence, Augmented Reality, Blockchain, Chatbots, Cloud Computing*

## 1. Introduction

In recent years, companies and organizations of all sizes and sectors increasingly focus on digital transformation. Generally, digital transformation refers to the transition from conventional to new and digitally enabled business models and operations, which adds value and promises organizational excellence. Schallmo et al. (2017) argue that there is no commonly accepted definition of the term, while Vial (2019) in his review found 28 sources offering 23 unique definitions. Based on the literature, Schallmo et al. (2017) define digital transformation (DT) as *“a framework that includes the networking of actors such as businesses and customers across all value-added chain segments and the application of new technologies. In order to increase the performance and reach of a company, DT involves companies, business models, processes, relationships, products, etc.”*.

According to the framework developed by Capgemini Consulting and MIT Center for Digital Business (2011), digital transformation of enterprises is built upon three main pillars-blocks: transformation of business model, transformation of operational processes and transformation of customer experience (Figure 1). Within these blocks, several elements are changing and boost the elements of the other block. For example, business model transformation refers to digital-modified business, new digital business and digital globalization. Transformation of operational processes refers to internal process digitization, worker enablement and performance management. Finally, digital transformation of customer experience refers to customer understanding, top line growth, and customer touch points. All blocks and elements are enabled and supported by digital capabilities, such as unified data and processes, analytics capability, business and IT integration and solution delivery.

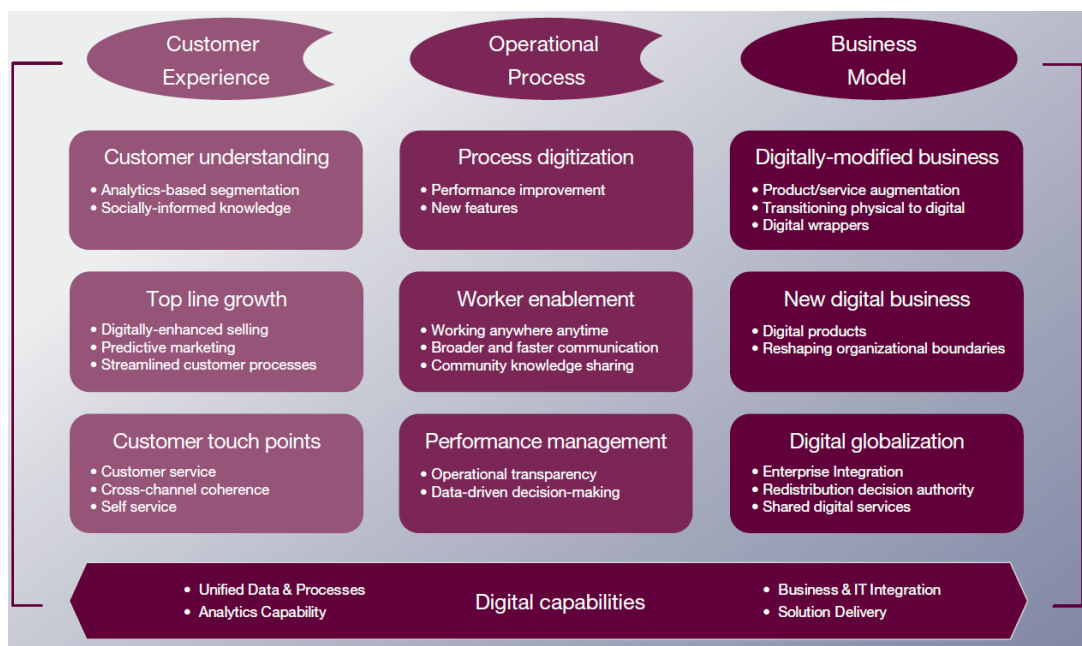


Figure 1. Building block of the digital transformation (Source: Capgemini Consulting, 2011, p. 17)

Mitroulis and Kitsios (2019) suggest that, in order to proceed to digital transformation, enterprises need to align four dimensions: i) the adoption and use of innovative technologies, ii) the implementation of innovative structural changes that lead to operational excellence, iii) changes in value creation and proposition and iv) financial aspects of digital transformation.

As far as innovative technologies (such as cloud computing, blockchain, artificial intelligence, augmented reality, big data analytics, internet of things, cyber-physical systems etc.) are concerned, they are often described as core elements of Industry 4.0 (Ghadge et al., 2020), in order to offer mass IT-enabled customization of manufactured goods, adaptation and reshape of production systems and operational models, automatic tracking and real-time communication between parts, products and

machines, application of human-machine interaction paradigms, IoT-enabled production optimization in smart factories, and provision of new services and business models for interaction, optimization and enhanced decision-making within the supply chain (Masood & Sonntag, 2020).

The aim of the present study is to focus on the first of the dimensions proposed by Mitroulis and Kitsios (2019), e.g. the adoption and use of innovative technologies for digital transformation. More specifically, through a literature review, this paper attempts to explore the role and the importance of innovative information and communications technologies, such as Artificial Intelligence, Augmented Reality, Blockchain, Chatbots and Cloud Computing in the digital transformation of companies and organizations towards Industry 4.0 and Industry 5.0 paradigms.

## 2. Artificial Intelligence

Artificial intelligence (AI) was first defined by John McCarthy in 1955 (Ertel, 2017) and enriched-expanded by various scientists, such as Rich (1983), Russell and Norvig (1995) and other researchers mentioned in Majid and Lakshmi (2023). There are several definitions published for Artificial Intelligence (AI), in an effort to differentiate it from other conventional information and communication technologies (ICT) (Enholtm et al., 2022). In general, most current definitions tend to consider AI as a set of methods, disruptive technologies and applications that are able to simulate and perform human-like tasks, such as learning, analysis, inferencing, problem solving and decision making.

The market of AI is constantly growing, together with its adoption and use by companies and organizations. According to Statista (2025a), the market for AI technologies amounted to around 244 billion USD in 2025 and is expected to grow up to over 800 billion USD in 2030. Similarly, the global AI-as-a-Service market is experiencing significant growth, from around 20.26 billion USD in 2025 will reach to 91.20 billion USD by 2030, with AIaaS platforms and marketplaces providing tools for the transformation of various industries (MarketsAndMarkets, 2025). In European Union, in 2024, 13,5% of businesses used AI technologies, while in 2023 the percentage was 8%. The country with the highest adoption rate of AI in businesses is Denmark (27,6%), followed by Sweden (25,1%), Belgium (24,7%) and Finland (24,4%), Netherlands and Luxemburg with 13%, while Bulgaria, Poland and Romania Romania and Serbia have the lowest rates (6,5%, 5,9% and 3,1% respectively) (Eurostat, 2025).

AI can be applied in a variety of business processes, such as demand and supply planning, inventory management, distribution-deliveries, predictive maintenance of equipment, customer service etc. (Enholtm et al., 2022). Benefits of AI in companies and organizations are increased productivity, accuracy in analysis and decision making, security and quality control, customer personalization, (Enholtm et al., 2022). There are several examples of companies, like Amazon, Uber, Tesla, Google, Alibaba and UPS, that seized AI's benefits and improved their competitive advantage (Lee et al., 2019). However, there are several issues-challenges that need to be considered, such as personnel reduction and unemployment, deployment costs, data security and privacy and ethics (Seele et al., 2021).

A study about the adoption of AI in employees of construction companies was performed by Na et al. (2022). The study was based on the Technology Acceptance Model (TAM) model, combined with the TOE (Technology-Organization-Environment) model, for the analysis of the factors that influence the acceptance and the intention to use AI. Findings showed that technological factors, together with external variables and employees' personality positively influence AI's perceived usefulness and perceived ease of use, while environmental factors influence negatively acceptance of AI. TAM and TOE models were also applied in the research of Chatterjee et al. (2021), who studied AI's adoption in Indian firms. The analysis of the responses showed that perceived usefulness of AI is influenced

positively by organizational competency and organizational readiness and negatively by organizational complexity. Finally, perceived ease of use positively influences perceived usefulness and intention to use AI and management support empowers the perceived ease of use and the intention to use AI.

### 3. Augmented Reality

The term Augmented Reality (AR) was coined in the beginning of '90s by Caudell and Mizell (1992), who were working at Boeing and used this term to describe a system that displays virtual graphics on a real workplace, in order to help employees for the aircrafts' cable assembling. Azuma (1997) defined AR as a system that combines real and virtual objects in real environment and in real time, while Schmalstieg and Hollerer (2016) describe it as technology that allows users to watch and interact with digital content in the real world. In this way, the user experience is more vivid, intense, realistic, interactive and captivating (Cipresso et al., 2018; Yim et al., 2017).

AR and VR (Virtual Reality) global market size is expected to grow from 22,12 billion USD in 2024 to 96,32 billion USD by 2029, with a compound annual growth rate (CAGR) of 34,2 in that period (MarketsAndMarkets, 2024). According to Statista (2025b), AR adoption will have a transformative impact across many sectors, providing opportunities for customer satisfaction, increased productivity, efficiency and cost savings.

The business use of AR applications refers mainly to marketing, for the enrichment of customer experience and the increase in their satisfaction (Bell et al., 2018; Poushneh & Vasquez-Parraga, 2017). AI not only improves skills, knowledge and commitment of customers in the digital world, but also creates new and attractive experiences (Yuan et al., 2021). With AR, customer can feel and experience the quality of clothing, shoes, cosmetics, furniture and other products, without physically interacting with them (Kowalczyk et al., 2021). AR applications are already used by several retailers, such as Tiffany & Co (Whang et al., 2021), L'Oréal (Hilken et al., 2017), Sephora (Smink et al., 2019), Nike (Hilken et al., 2018), Converse (Whang et al., 2021), Zara (Yuan et al., 2021) and IKEA (McLean & Wilson, 2019), for the improvement of customer experience, the strengthening of customer loyalty and the attraction of new customers.

Du et al. (2022) performed a systematic literature review on 99 papers from 1990-2021 that studied the adoption of AR in retail, tourism and marketing. In 15 studies the TAM model was applied, in 7 the SOR (Stimulus-Organism-Response) Framework was used, while in the other studies were based on Uses and gratifications theory (UGT), Theory of Reasoned Action (TRA) and Unified Theory of Acceptance and Use of Technology (UTAUT). According to the studies, in the retail industry AR improved customers' attitude as well as their satisfaction and intention to use again this technology and buy the products offered. In tourism, the application of AR improved tourist experience, by providing more interactive, pleasant and personalized travel experiences. Finally, AR in marketing mainly focused on applications for smartphones, for the provision of interactive and attractive customer experience. Another recent research effort about AR was conducted by Nassereddine et al. (2022), where they examined the application of AR in the construction industry. Through their study, the authors argue that AR can transform the construction industry, by providing real time information and guidance to workers, thus improving the accuracy and quality of design, the efficiency and effectiveness of projects, as well as the security of workforce. A main obstacle-barrier for AR adoption is the high cost of AR hardware and software, something that prevents (up to now) small and medium-sized companies from investing in. However, as with other cutting-edge technologies, costs are expected to decline after some period of the technology use in the market.

#### 4. Blockchain

Blockchain is a time-stamped series of data records-ledgers (i.e. block), managed by cluster of computers (P2P network), not owned by any single entity (decentralized). Each of these blocks is validated-verified and linked to the others using cryptographic principles (i.e. chain). All copies are updated and validated simultaneously, while data is immutable and available to all parties. With the use of blockchain, there is a system-wide consensus on the validity of an entire history of transactions, which are performed under specific and common agreements (smart contracts). All participants in the supply chain as well as the final consumer can trace the records and the history of the transactions (Seebacher & Schuritz, 2017; Swan, 2018).

In 2018, Tapscott and Tapscott argued that blockchain is a revolutionary technology that does not only have the power to transform financial services and business activities, but to change the economy and the whole world (Tapscott & Tapscott, 2018). Indicative sectors that blockchain can be applied are supply chain, financial and banking services, insurance, healthcare, energy, construction, real estate etc. (Zheng et al., 2018). World Economic Forum estimated that by 2027, 10% of global GDP will be stored on blockchain related technology (World Economic Forum, 2024). Moreover, according to Fortune Business Insights (2025a), the need for blockchain technology in many business sectors will be stimulated by growing technological innovations, thus formulating a market with a projected value of 393,42 billion USD by 2032.

One of issues that affect blockchain adoption is the carbon footprint and the amount of energy needed for the operation and maintenance of consensus mechanisms and related applications (Zheng et al., 2018). Also, the lack of standards may lead in compatibility issues between different blockchain networks (Swan, 2018). Finally, the development and operating costs are still high, thus preventing small and medium companies from investing in, unless they participate in a relatively low-cost permissioned consortium blockchain network.

A study by Bhardwaj et al. (2021) examined the factors that influence the intention of small and medium-sized companies in India to adopt blockchain in their supply chains. The research was based on TAM, TOE and DOI (Diffusion of Innovation) models and the results showed that relative advantage, technology compatibility, complexity, technological readiness, top management support, cost concerns, perceived usefulness and vendor support, significantly influence the blockchain technology adoption intention. Other factors, such as security concerns, perceived ease of use and government policy do not seem to influence adoption intention. Another research, by Albayati et al. (2020), focused on the customer perspective approach about the acceptance of blockchain technology in financial transactions. The authors applied the TAM model, enriched with other external factors, such as trust, regulatory support, social influence, design and experience. Findings show that customer trust is strongly influenced by regulatory support from the government and by the level of personal experience to use blockchain applications.

#### 5. Chatbots

According to Khan and Das (2018), a chatbot is a computer program based on artificial intelligence, which interacts with the user, processes the input-questions provided by the user and delivers smart and quick answers based on pre-defined rules or on machine learning and natural language processing (McTear, 2020; McTear et al., 2016).

Chatbots can be used in several activities, such as user and customer support, product recommendation, pre-sales and after-sales activities, process automation etc. and companies like Apple, Amazon, Facebook and IBM have been using them for several years. In the U.S., the sector with the highest chatbot adoption rate is marketing and advertising (37%), while healthcare has the

lowest adoption rate with 15% (Statista, 2023). Also, the global chatbot market size value will rise from 396 million USD in 2019 to 1,95 billion USD in 2027 (Fortune Business Insights, 2025b).

Some of chatbots advantages mentioned in the literature are the following (Arsenijevic & Jovic, 2019; Buhalis & Yen, 2020; Rietz et al., 2019): 24/7 availability, increased effectiveness (a chatbot can serve many users simultaneously), customization and personalization according to customer's needs, increased productivity (chatbots can handle routine and repetitive processes), better customer support, elimination of mistakes and reduction in workload, cost reduction, provision of a certain quality of service regardless of the employee's knowledge and character, etc. On the other hand, disadvantages of chatbots include purchase and development cost, inability to solve more complex issues (that a human would solve), poor language recognition, lack of personal contact that may lead in worse customer experience, inadequate social sensitivity, need for constant updates, security issues etc. (Selamat and Windasari, 2021).

Sharma et al. (2022) explored the reasons of AI chatbot intention implementation in 292 small and medium enterprises with the use of TOE (Technology, Organization, Environment) framework. According to their findings, adoption intention is positively related to perceived relative advantage of chatbots, top management support, financial support-resources, employees' capability (knowledge), and negatively related to cost and perceived complexity to intention. Finally, the relationship between chatbot adoption intention and environment factors (competitive pressure, customer pressure and vendor support) is not statistically significant. The authors propose the implementation of similar research efforts in other countries (especially in smaller and developing nations), that will focus more on the business perspective of chatbot adoption and not so much on the customer perspective, which is an issue that has been substantially studied in the literature.

Another interesting study was performed by Kvale et al. (2020), where they analyzed 406 dialogues between customers and chatbot of the customer service department in a large telecom provider, in order to understand and improve the capabilities of the chatbot. The topics of the analysis were the chatbot's ability to resolve customers' requests, the quality in conversation-dialogues, and suggestions for improvements of the chatbot knowledge base. The results of the analysis showed that 24% of the dialogues were characterized as resolved, 25% as immediate handover, 34% as unresolved, 13% as irrelevant customer input and 4% as uncertain. As far as the quality in conversation is concerned, a percentage of around 60% was characterized as excellent, good and acceptable, while a percentage of 10% was characterized as "reasonable miss" and a percentage of 31% as "poor". Finally, the suggestions for improvements mainly refer to the need for further chatbot training by enriching the knowledge base. In conclusion, authors argue that chatbots are a valuable source of customer understanding and that successful conversations depend on the customer, the chatbot and the service provider.

## 6. Cloud computing

Computing represents the emergence of a new computing paradigm (Cegielski et al., 2012), that is rapidly changing the conventional way information technology (IT) products and services are delivered (Wang et al., 2016). With cloud computing, users and companies-organizations can have access to ICT infrastructure, without owning or administering it and only paying for the infrastructure they need and use. This allows companies to reduce ICT total ownership cost, while at the same time provides increased flexibility, scalability, efficiency and faster responses to market needs (Paul & Ghose, 2012). Other cloud computing advantages refer to more efficient mechanisms of data storage, backup and recovery, as well as improved collaboration through the use of common platforms, services, files etc. (Puri et al., 2019). Cloud computing services are provided through several deployment models (public cloud, private cloud, community cloud, hybrid cloud) and service models

(Infrastructure as a Service - IaaS, Platform as a Service - PaaS) and Software as a Service - SaaS) (Hsu et al., 2014).

The adoption of cloud computing offers significant advantages and can be applied to all sectors of the economy, formulating a growing market and a crucial driver for economic growth, with serious impacts for users of cloud computing services, providers and the society as a whole (Nanos et al., 2019). According to Eurostat (2025), 45 % of EU enterprises bought cloud computing services in 2023, mainly for e-mail hosting (83%), file storage (68%) and office software (66%). As displayed at Figure 2, in Scandinavian countries (Finland, Sweden, Denmark, Norway) the majority of enterprises bought cloud computing services, while in Balkan countries (such as Greece, Romania, Bulgaria) less than 25 % of enterprises did so.

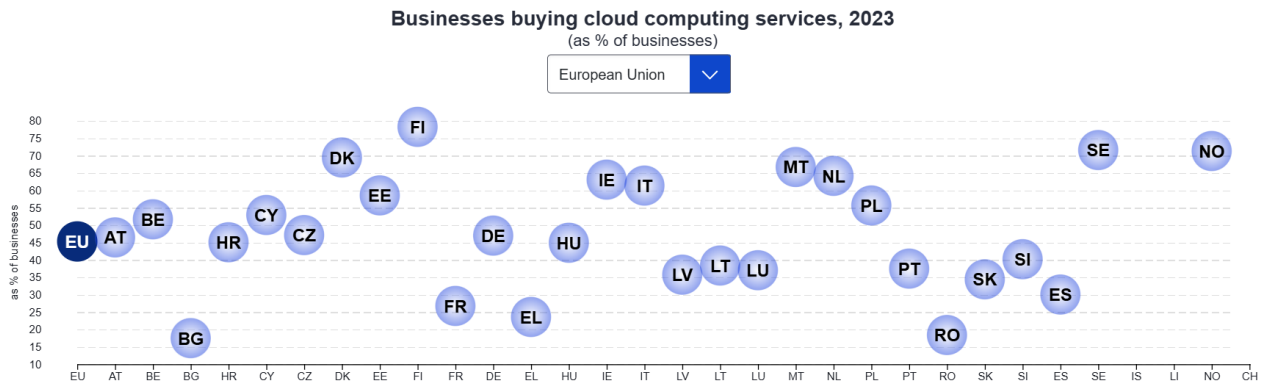


Figure 2. Businesses buying cloud computing services, 2023 (as % of businesses), (Source: Eurostat, 2025)

Concerning the adoption of cloud computing in small and medium enterprises, Khayer et al. (2021) performed a study that aimed at the analysis of the factors that influence the adoption and at the measurement of the impact of cloud adoption into firm's performance. The research was based on the TOE and UTAUT models and responses were collected from 372 owners or managers of SMEs. According to the findings of the research, notable predictors of cloud computing adoption are factors such as performance and effort expectancy, absorptive capacity, data security and privacy and perceived trust. Finally, cloud computing adoption positively influences firm performance directly and through organizational agility.

## 7. Conclusions

The present paper presented a detailed overview on innovative information and communications technologies, such as Artificial Intelligence, Augmented Reality, Blockchain, Chatbots and Cloud Computing and their role in the digital transformation of companies and organizations. A similar overview of other disruptive technologies (e.g. Internet of Things, Virtual Reality, Digital Twin, Robotic Process Automation, Wireless Sensor Networks, Autonomous Robots etc.) that support and boost digital transformation may also be conducted. Finally, further studies and empirical research efforts is needed, about the adoption, use and impact of these technologies, both on companies – organizations and on consumers, in a wide range of activities-processes such as marketing, sales, finance, warehouse management, decision-making etc.

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# **Blockchain in Real Estate: legal barriers, technological advances, and the path to integration**

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## **Abstract**

As blockchain matures beyond cryptocurrency, its potential to transform the real estate sector is gaining momentum. This paper reviews the state of blockchain integration in real estate, focusing on two major fronts: land registry modernization and the tokenization of property assets. Drawing from 40 peer-reviewed studies, we map current trends, leading authors, and emerging applications. While blockchain promises transparency, efficiency, and broader access to investment, legal and institutional barriers still hold back full-scale adoption. We argue that the next breakthrough lies in bridging the gap between public land systems and private tokenized platforms, unlocking a new era of real estate innovation.

**Keywords:** *Blockchain, Real Estate, Tokenization, Decentralized Finance (DeFi), Smart Contracts*

## **1. Introduction**

Emerging technologies are increasingly driving productivity growth and reshaping industries. Nowhere is this more evident than in the financial and technology markets, where the rise of artificial intelligence (AI), the Internet of Things (IoT), and blockchain technology is reshaping business models and infrastructure. Technology-focused indices such as NASDAQ have outperformed broader markets, reflecting investor confidence in the transformative potential of these innovations.

Among emerging digital technologies, blockchain, a specific implementation of distributed ledger technology (DLT), offers a decentralized, transparent, and tamper-resistant mechanism for recording transactions. Although the conceptual foundations of DLT predate Bitcoin, it was Satoshi Nakamoto's (2008) white paper that introduced the first operational blockchain as part of a peer-to-peer electronic cash system. Since then, blockchain technology has evolved well beyond cryptocurrencies, enabling a wide range of applications in finance, supply chains, digital identity, and beyond.

The broader blockchain ecosystem now includes platforms like Ethereum, which support programmable smart contracts and decentralized applications (DApps). These developments have prompted growing academic and industry interest in blockchain's real-world applications, particularly

in finance and asset management. However, despite significant technological progress, real-world adoption remains fragmented, especially in traditional and highly regulated sectors such as real estate.

This paper focuses on the financial applications of blockchain within the real estate sector, a domain where innovation has been slower to materialize compared to the broader blockchain landscape. Through a structured review of the literature, we aim to assess the current state of blockchain adoption in real estate, identify key developments, and outline the challenges that must be addressed to enable broader integration.

## **2. Applications of Blockchain Technology**

Blockchain technology was initially introduced as a peer-to-peer electronic payment system, most notably through Bitcoin. Over time, however, it became apparent that the underlying distributed ledger structure had broader applicability across numerous sectors. Among the first to expand blockchain's scope was Ethereum, which was formulated by Vitalik Buterin (2014) and launched in 2015, with the goal of enabling decentralized applications (DApps) through programmable smart contracts. Ethereum's platform aimed to deliver scalability, standardization, and interoperability, foundations that have since enabled the emergence of a wide range of decentralized use cases.

These developments have given rise to a layered blockchain ecosystem. At the base are Layer 1 protocols, such as Ethereum, which provide the foundational infrastructure. Layer 2 solutions build on these foundations to enhance scalability and reduce transaction costs. This layered architecture has supported the emergence of diverse blockchain-based applications, including decentralized finance (DeFi), digital art via non-fungible tokens (NFTs), virtual environments (metaverses), online gaming, and decentralized data storage.

One of blockchain's most transformative features lies in its ability to automate trust-based processes through smart contracts. This enables the execution of transactions and processes without the need for traditional intermediaries. As a result, tasks that previously required administrative oversight can now be completed securely and transparently, often at significantly lower cost and time.

These capabilities have drawn interest from sectors that involve complex and trust-dependent processes, such as supply chain management, identity verification, and, notably, financial services and real estate. As research and development continue to expand, the potential for blockchain to streamline operations, enhance data integrity, and redefine asset ownership grows increasingly tangible.

## **3. Blockchain in the World of Finance**

### **3.1. Decentralized Finance (DeFi)**

From its inception, blockchain technology has been closely associated with financial transactions. While Bitcoin introduced a decentralized method of transferring value, it was the evolution of decentralized finance that expanded blockchain's role within the financial sector. DeFi refers to a suite of financial applications built on blockchain platforms that enable peer-to-peer financial services without the need for centralized intermediaries.

One of the earliest and most influential DeFi protocols was MakerDAO, which launched in 2017 and allowed users to lend and borrow crypto assets through smart contracts. These protocols mimic traditional banking functions, such as savings and loans, but automate the process through code rather than institutions. Users retain full custody of their assets, distinguishing DeFi from centralized finance (CeFi), where intermediaries control user funds.

Beyond lending and borrowing, DeFi has evolved to support complex financial mechanisms. For example, protocols like Uniswap and Aave on Ethereum, introduced automated market makers (AMMs) and liquidity pools (LPs), which facilitate token trading without order books. Liquidity providers contribute assets to these pools and earn transaction fees in return. Smart contracts dynamically adjust prices based on supply and demand using formulas such as the constant product rule.

This new infrastructure enables decentralized exchanges (DEXs) to operate efficiently, empowering users with greater control over their financial assets and transactions. Nevertheless, DeFi systems carry their own risks, including protocol vulnerabilities and regulatory uncertainty, which researchers have begun to systematically categorize and assess.

### 3.2. Tokenization

Tokenization is a cornerstone of blockchain's financial utility. It refers to the process of representing real or digital assets as tokens on a blockchain. The most straightforward example is stablecoins, digital tokens pegged to fiat currencies such as the U.S. dollar (e.g., USDT, DAI). However, tokenization has extended to a wide array of assets, including equities, bonds, real estate, and even art.

Non-fungible tokens (NFTs) represent unique digital assets and have primarily gained traction in the creative industries. However, their underlying logic is increasingly being explored for physical asset representation, such as property ownership, intellectual property rights, and supply chain items. This allows for fractional ownership, improved liquidity, and automated transfer of ownership through smart contracts.

Tokens may serve various functions depending on their design and legal treatment. Common classifications, like the ones mentioned in Willcocks et al. (2022), include:

- *Payment tokens*: digital representations of value used for transactions.
- *Utility tokens*: access tools for services within a blockchain ecosystem.
- *Investment tokens*: representations of ownership or entitlement to future profits.

The rise of token economies illustrates how blockchain can redefine ownership and market structures. By enabling programmable and transferable representations of real-world assets, tokenization acts as a bridge between the physical and digital economies, opening up new models of financing, investment, and governance.

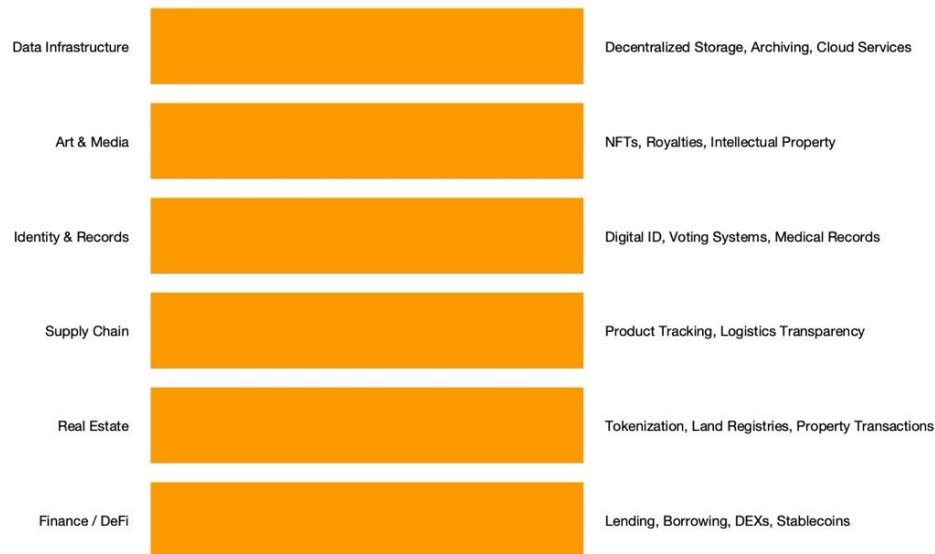


**Figure 1:** Key applications of blockchain technology by sector.

### 3.3. Tokenization in Real Estate

Tokenization represents one of the most promising financial applications of blockchain technology in the real estate sector. At its core, tokenization refers to the process of creating digital representations of real-world assets, such as land or property, on a blockchain. These digital tokens can then be exchanged, fractionally owned, or embedded within smart contracts that automate aspects of ownership, governance, or revenue distribution.

The initial wave of tokenization was led by the creation of stablecoins, crypto-assets pegged to fiat currencies like the US Dollar or the Euro. While these serve a financial function, tokenization has since expanded to include physical assets. Non-Fungible Tokens, for instance, provide a secure and verifiable method for representing unique items on-chain. Originally popularized in the context of digital art, NFTs also offer a blueprint for property tokenization by enabling secure proof of ownership and traceability.

The potential to tokenize real estate offers multiple benefits:

- Fractional ownership lowers barriers to entry for small investors.
- Increased liquidity through secondary markets.
- Transparent transaction histories, reducing fraud and administrative overhead.
- Automation via smart contracts for rental agreements, sales, or revenue distribution.

Although some early-stage projects, such as RealT in Detroit, have demonstrated the viability of tokenized real estate models, their structures often resemble traditional investment schemes. For example, investors may hold tokens representing shares in a company that owns the property, rather than direct ownership of the property itself on a blockchain.

Legal design remains a significant obstacle. As noted by various researchers, including Szabo (2005) and Garcia-Teruel & Simón-Moreno (2021), full integration requires tokens to be legally recognized as titles of ownership. Some studies, such as Avci & Erzurumlu (2023), propose instruments inspired

by Islamic finance models like Sukuk, which are structured to distribute income while maintaining asset-backing compliance.

Additionally, technological and legal innovations are converging. Proposals involving Collaborative Smart Contracts (CoSC) and Trusted Node Consensus Algorithms (TNCA) aim to bridge blockchain systems with governmental land registries. These efforts attempt to provide legal certainty while enabling automated and decentralized transactions.

Ultimately, tokenization has the potential to transform how real estate assets are owned, accessed, and transferred. However, realizing this potential requires both technological maturity and a legal framework that accommodates the digital representation of property rights.

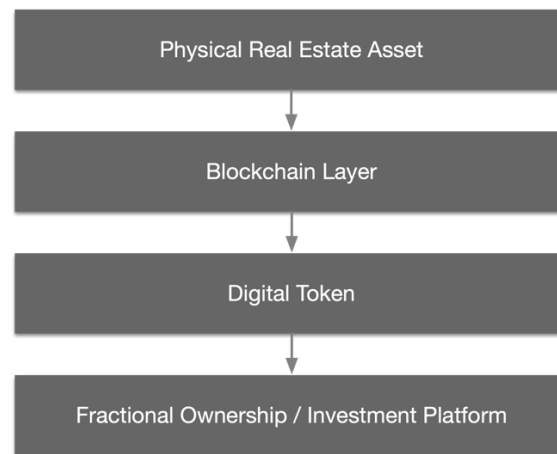


*Figure 2: Tokenization model of real estate assets.*

## 4. Research Methodology

### 4.1 Database and Search Strategy

To explore the integration of blockchain technology in the real estate sector, we conducted a structured literature review using the Scopus database, one of the most comprehensive repositories of peer-reviewed academic content. Our search employed the following Boolean query:

((real AND estate) OR land) AND (blockchain OR (distributed AND ledger)) AND (tokenization OR application OR integration)

Initial queries using broader or less structured terms yielded large volumes of irrelevant or tangential results. Therefore, the refined query was selected to focus specifically on papers at the intersection of blockchain and real estate, with particular interest in financial applications and integration strategies.

This search returned a total of 481 papers, with most contributions originating from India. Subject-area classification revealed a balanced distribution across disciplines, with computer science and engineering leading in publication volume.

### 4.2 Inclusion and Exclusion Criteria

To ensure academic rigor, we adopted the following inclusion criteria:

- Peer-reviewed journal articles.

- Published in English.
- Indexed in Scopus.
- Direct relevance to blockchain applications in real estate.

Following the methodology of Rejeb et al. (2022), only journal articles were included, excluding conference proceedings, book chapters, and working papers. This filtering process reduced the initial corpus from 481 to 121 papers.

Further refinement was based on quality indicators: we limited our final selection to articles published in Q1 or Q2 journals, according to the Scimago Journal Rank (SJR) in their respective subject areas. This yielded a final sample of 40 high-quality articles, which were subjected to detailed thematic analysis.

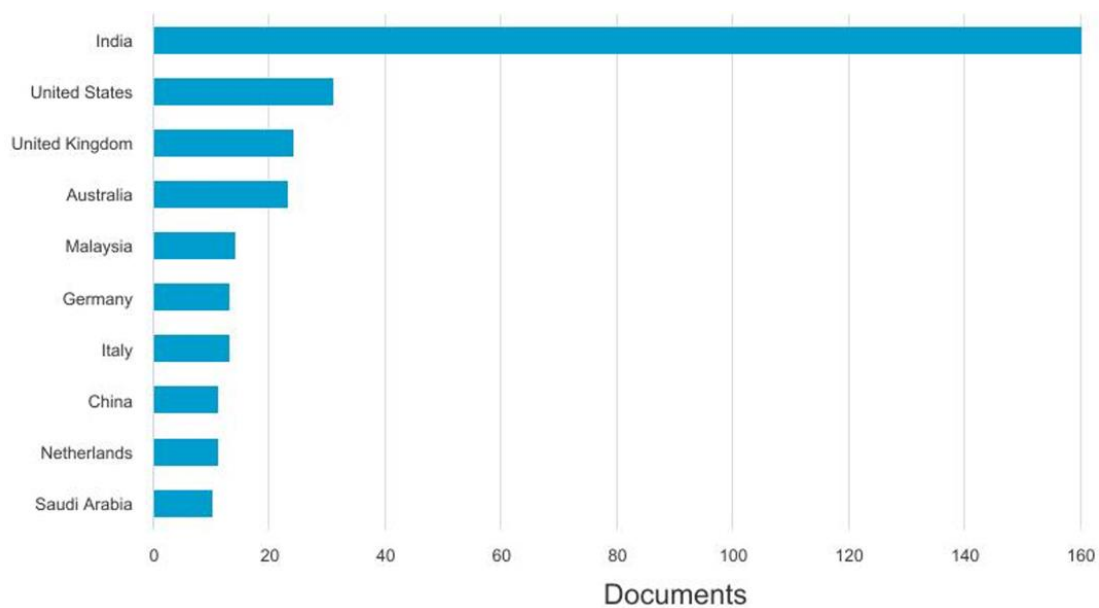


**Figure 3:** Documents by country or territory. Scopus. Copyright © 2025 Elsevier B.V.

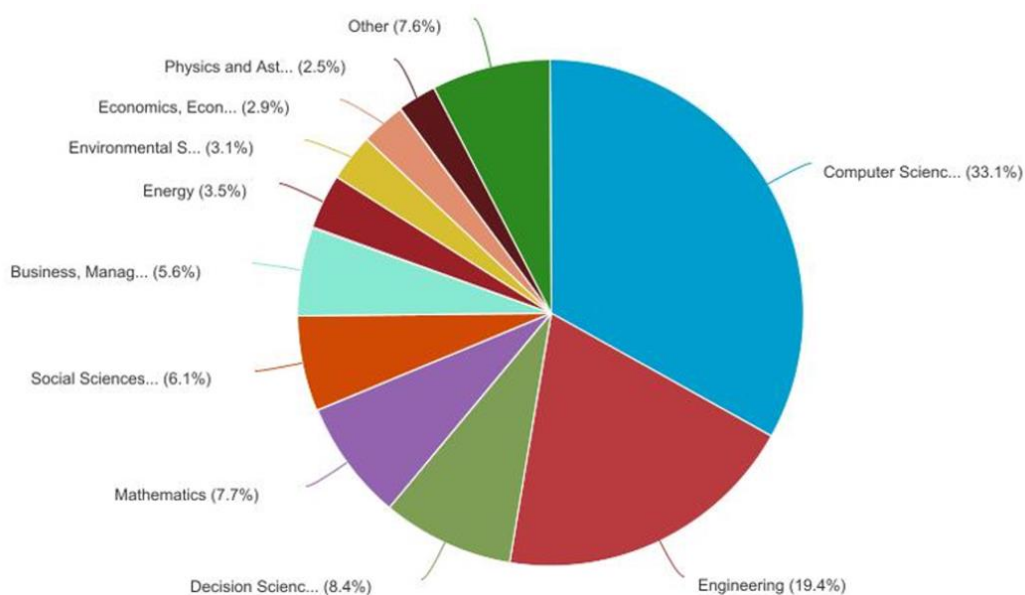


**Figure 4:** Documents by subject area. Scopus. Copyright © 2025 Elsevier B.V.

### 4.3 Bibliometric Analysis

To identify dominant research themes and key contributions, we performed a bibliometric analysis using VOSviewer. The first stage involved a keyword co-occurrence analysis, with a minimum threshold of five occurrences per keyword, following the example of Tanrivermis et al. (2024). To eliminate redundancy, a thesaurus file was created to merge semantically identical terms (e.g., “blockchain” and “block-chain”).

The final map included 15 unique keywords, grouped into four clusters, with the strongest nodes being:

- *Blockchain* (101 occurrences, link strength 143).
- *Smart Contracts* (33 occurrences).
- *Real Estate* (30 occurrences).

We also conducted a bibliographic coupling analysis, applying a citation threshold of two, again in accordance with Tanrivermis et al. (2024). Among the 121 reviewed articles, 86 met this criterion. The analysis revealed a divergence between highly cited articles and those with high link strength, indicating that influential research is not always the most interconnected within the field. For example, Lemieux (2016) had the most citations but no link strength, while Stefanovic et al. (2022) had the highest link strength but modest citation numbers.

| Keyword                       | Occurrences | Total Link Strength |
|-------------------------------|-------------|---------------------|
| Blockchain                    | 101         | 143                 |
| Smart Contracts               | 33          | 76                  |
| Real Estate                   | 30          | 68                  |
| Distributed Ledger Technology | 14          | 37                  |
| Tokenization                  | 13          | 28                  |
| Decentralized                 | 10          | 27                  |
| Ethereum                      | 7           | 23                  |
| Internet of Things            | 10          | 17                  |
| Land Administration           | 5           | 15                  |
| Land Registration             | 9           | 14                  |
| Security                      | 7           | 14                  |
| Smart City                    | 6           | 14                  |
| Supply Chain Management       | 5           | 13                  |
| Artificial Intelligence       | 6           | 8                   |
| Technological Development     | 5           | 7                   |

**Table 1:** Occurrences and total link strength for keywords.

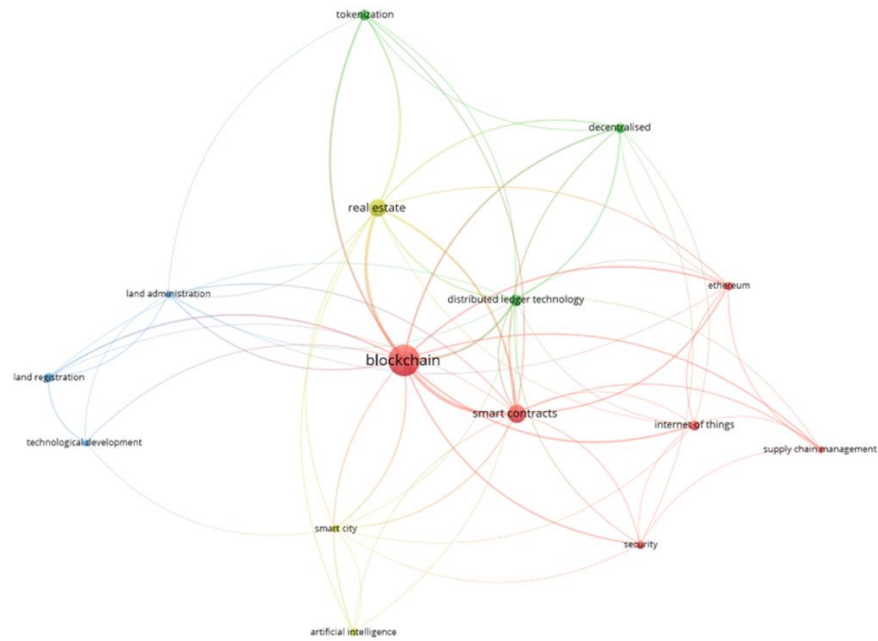


**Figure 5:** Keyword Co-Occurrence Analysis. VOSviewer.

| Authors                                                                                                                                                                                             | Citations | Total Link Strength |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|---------------------|
| Lemieux V.L.                                                                                                                                                                                        | 383       | 0                   |
| Kshetri N.                                                                                                                                                                                          | 191       | 2                   |
| Bamakan S.M.H.; Nezhadsistani N.; Bodaghi O.; Qu Q.                                                                                                                                                 | 150       | 10                  |
| Grover P.; Kar A.K.; Janssen M.                                                                                                                                                                     | 125       | 49                  |
| Dakhli Z.; Lafhaj Z.; Mossman A.                                                                                                                                                                    | 101       | 21                  |
| Li M.; Shen L.; Huang G.Q.                                                                                                                                                                          | 96        | 9                   |
| Ullah F.; Al-Turjman F.                                                                                                                                                                             | 93        | 45                  |
| Garcia-Teruel R.M.                                                                                                                                                                                  | 84        | 21                  |
| Wouda H.P.; Opdenakker R.                                                                                                                                                                           | 83        | 37                  |
| Bosu A.; Iqbal A.; Shahriyar R.; Chakraborty P.                                                                                                                                                     | 70        | 29                  |
| Kiu M.S.; Chia F.C.; Wong P.F.                                                                                                                                                                      | 66        | 26                  |
| Khadke S.; Gupta P.; Rachakunta S.; Mahata C.; Dawn S.; Sharma M.; Verma D.; Pradhan A.; Krishna A.M.S.; Ramakrishna S.; Chakraborty S.; Saianand G.; Sonar P.; Biring S.; Dash J.K.; Dalapati G.K. | 66        | 11                  |
| Bhattacharya P.; Saraswat D.; Savaliya D.; Sanghavi S.; Verma A.; Sakariya V.; Tanwar S.; Sharma R.; Raboaca M.S.; Manea D.L.                                                                       | 62        | 6                   |
| Bodkhe U.; Tanwar S.; Bhattacharya P.; Kumar N.                                                                                                                                                     | 53        | 6                   |
| Konashevych O.                                                                                                                                                                                      | 51        | 47                  |
| Sladić G.; Milosavljević B.; Nikolić S.; Sladić D.; Radulović A.                                                                                                                                    | 51        | 21                  |
| Sharma P.; Jindal R.; Borah M.D.                                                                                                                                                                    | 50        | 43                  |
| Saari A.; Vimpari J.; Junnila S.                                                                                                                                                                    | 49        | 38                  |
| Bennett R.M.; Pickering M.; Sargent J.                                                                                                                                                              | 47        | 43                  |
| Garcia-Teruel R.M.; Simón-Moreno H.                                                                                                                                                                 | 44        | 6                   |
| Ferreira A.                                                                                                                                                                                         | 43        | 29                  |
| Shou M.; Domenech T.                                                                                                                                                                                | 42        | 7                   |
| Davies F.T.; Garrett B.                                                                                                                                                                             | 37        | 1                   |

|                                                                                                                      |    |    |
|----------------------------------------------------------------------------------------------------------------------|----|----|
| Kaczorowska M.                                                                                                       | 36 | 12 |
| Bennett R.; Miller T.; Pickering M.; Kara A.-K.                                                                      | 35 | 51 |
| Yadav A.S.; Singh N.; Kushwaha D.S.                                                                                  | 33 | 43 |
| Yadav A.S.; Agrawal S.; Kushwaha D.S.                                                                                | 33 | 7  |
| Rodima-Taylor D.                                                                                                     | 32 | 9  |
| Shahaab A.; Khan I.A.; Maude R.; Hewage C.; Wang Y.                                                                  | 31 | 26 |
| Baum A.                                                                                                              | 31 | 2  |
| Grinyaev S.N.; Medvedev D.A.; Pravikov D.I.; Samarin I.V.; Sherbakov A.Y.U.                                          | 30 | 0  |
| Frikha T.; Ktari J.; Zalila B.; Ghorbel O.; Amor N.B.                                                                | 29 | 1  |
| Yadav A.S.; Kushwaha D.S.                                                                                            | 29 | 8  |
| Yapicioglu B.; Leshinsky R.                                                                                          | 27 | 7  |
| Mintah K.; Baako K.T.; Kavaarpuo G.; Otchere G.K.                                                                    | 27 | 24 |
| Veuger J.                                                                                                            | 25 | 6  |
| Swinkels L.                                                                                                          | 24 | 10 |
| Veeramani K.; Jaganathan S.                                                                                          | 21 | 22 |
| Stefanovic M.; Przulj D.; Ristic S.; Stefanovic D.; Nikolic D.                                                       | 20 | 55 |
| Oberhauser D.                                                                                                        | 20 | 3  |
| Chow Y.L.; Tan K.K.                                                                                                  | 16 | 2  |
| Akhmetbek Y.; Špaček D.                                                                                              | 15 | 4  |
| Morena M.; Truppi T.; Pavesi A.S.; Cia G.; Giannelli J.; Tavoni M.                                                   | 15 | 18 |
| Konhäuser W.                                                                                                         | 14 | 0  |
| Serrano W.                                                                                                           | 14 | 1  |
| Jebril I.; Al-Zaqeba M.A.A.; Al-Khawaja H.A.; Al Obaidy A.L.A.; Marashdah O.S.                                       | 13 | 20 |
| Proskurovska A.; Dörny S.                                                                                            | 13 | 30 |
| S.S. V.C.; S. A.H.; Albaaji G.F.                                                                                     | 12 | 1  |
| Goyal A.; Kanyal H.S.; Sharma B.                                                                                     | 12 | 27 |
| Manoj Kumar N.; Chopra S.S.                                                                                          | 12 | 0  |
| Alotaibi L.S.; Alshamrani S.S.                                                                                       | 12 | 11 |
| Mariappan S.                                                                                                         | 10 | 0  |
| Worzala E.; Souza L.A.; Koroleva O.; Martin C.; Becker A.; Derrick N.                                                | 9  | 0  |
| Somantri A.; Surendro K.                                                                                             | 9  | 0  |
| Gaba S.; Khan H.; Almalki K.J.; Jabbari A.; Budhiraja I.; Kumar V.; Singh A.; Singh K.K.; Askar S.S.; Abouhawwash M. | 9  | 1  |
| Kumari K.; Saini K.                                                                                                  | 9  | 12 |
| Ortega J.C.U.; Rodríguez-Molina J.; Martínez-Núñez M.; Garbajosa J.                                                  | 8  | 0  |
| Das S.; Mohanta B.K.; Jena D.                                                                                        | 8  | 3  |
| Gonçalves J.P.B.; de Resende H.C.; Villaca R.S.; Municio E.; Both C.B.; Marquez-Barja J.M.                           | 8  | 7  |
| Mendi A.F.; Demir Ö.; Sakaklı K.K.; Çabuk A.                                                                         | 8  | 18 |
| Akinradewo O.; Aigbavboa C.; Oke A.; Edwards D.                                                                      | 7  | 13 |
| Avci G.; Erzurumlu Y.O.                                                                                              | 7  | 24 |
| Hammad M.; Iqbal J.; Hassan C.A.U.; Hussain S.; Ullah S.S.; Uddin M.; Malik U.A.; Abdelhaq M.; Alsaqour R.           | 7  | 10 |
| Hirsh S.; Alman S.; Lemieux V.; Meyer E.T.                                                                           | 7  | 6  |
| Mehendale D.K.; Masurekar R.S.; Patil H.V.                                                                           | 7  | 0  |

|                                                                       |   |    |
|-----------------------------------------------------------------------|---|----|
| Joshi S.; Choudhury A.                                                | 6 | 18 |
| Nasarre-Aznar S.                                                      | 6 | 0  |
| Ghosh A.; Lavanya; Hassija V.; Chamola V.; Saddik A.E.                | 5 | 5  |
| Wang X.; Hong Y.; He X.                                               | 5 | 2  |
| Ketbi M.A.; Shuaib K.; Barka E.; Gergely M.                           | 5 | 0  |
| Crandall J.                                                           | 4 | 1  |
| Argelich Comelles C.                                                  | 4 | 0  |
| Zhitomirskiy E.; Schmid S.; Walther M.                                | 3 | 3  |
| Timuçin T.; Biroğul S.                                                | 3 | 12 |
| Baptista N.; Januario J.F.; Cruz C.O.                                 | 3 | 41 |
| Yong K.-J.; Tay E.S.; Khong D.W.K.                                    | 3 | 16 |
| Proskurovska A.                                                       | 3 | 31 |
| Abualhamayl A.; Almalki M.; Al-Doghman F.; Alyoubi A.; Hussain F.K.   | 3 | 9  |
| Schwarzc S.L.                                                         | 3 | 0  |
| Sheikh S.; Gilliland A.J.; Kothe P.; Lowry J.                         | 2 |    |
| Creta F.; Tenca F.                                                    | 2 | 36 |
| Wang F.                                                               | 2 | 22 |
| Margret M.K.; Julie E.G.                                              | 2 | 3  |
| Hrouga M.                                                             | 2 | 5  |
| Messié V.; Fromentoux G.; Labidurie N.; Radier B.; Vaton S.; Amigo I. | 2 | 17 |
| Gupta A.; Gupta B.; Gola K.K.                                         | 2 | 0  |

**Table 2:** Authors, citations, and total link strength.

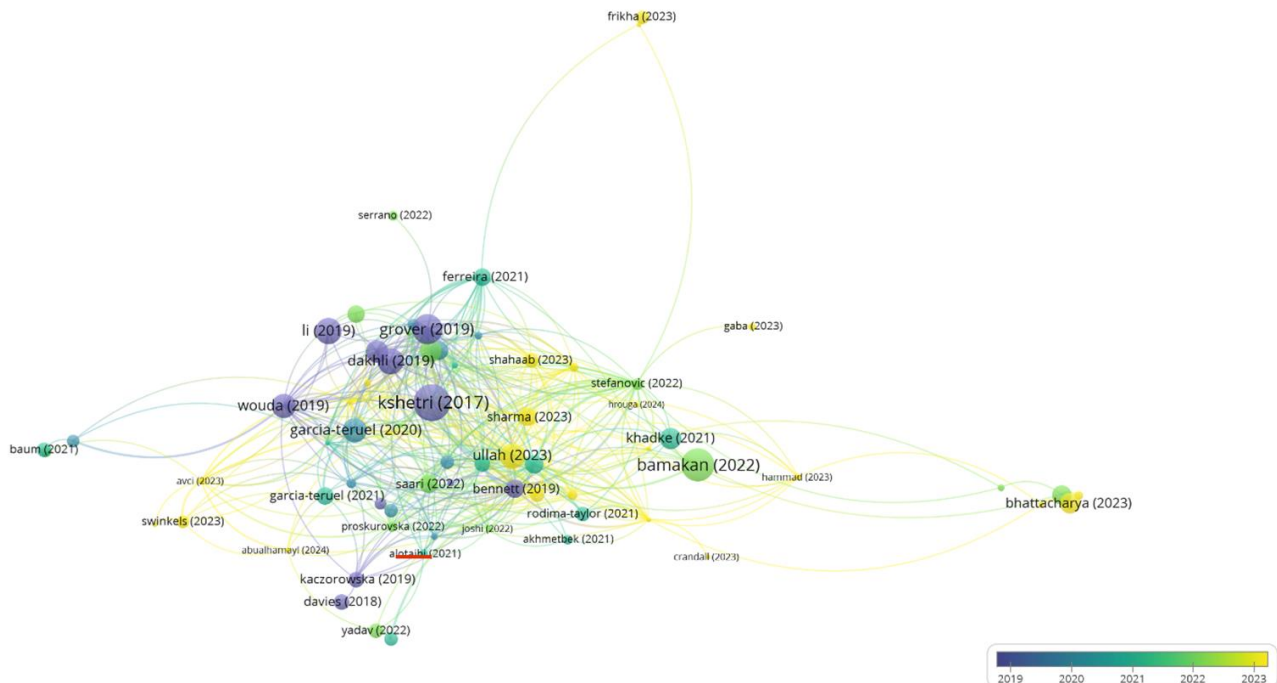


**Figure 6:** Bibliographic Coupling Analysis (citations map). VOSviewer.

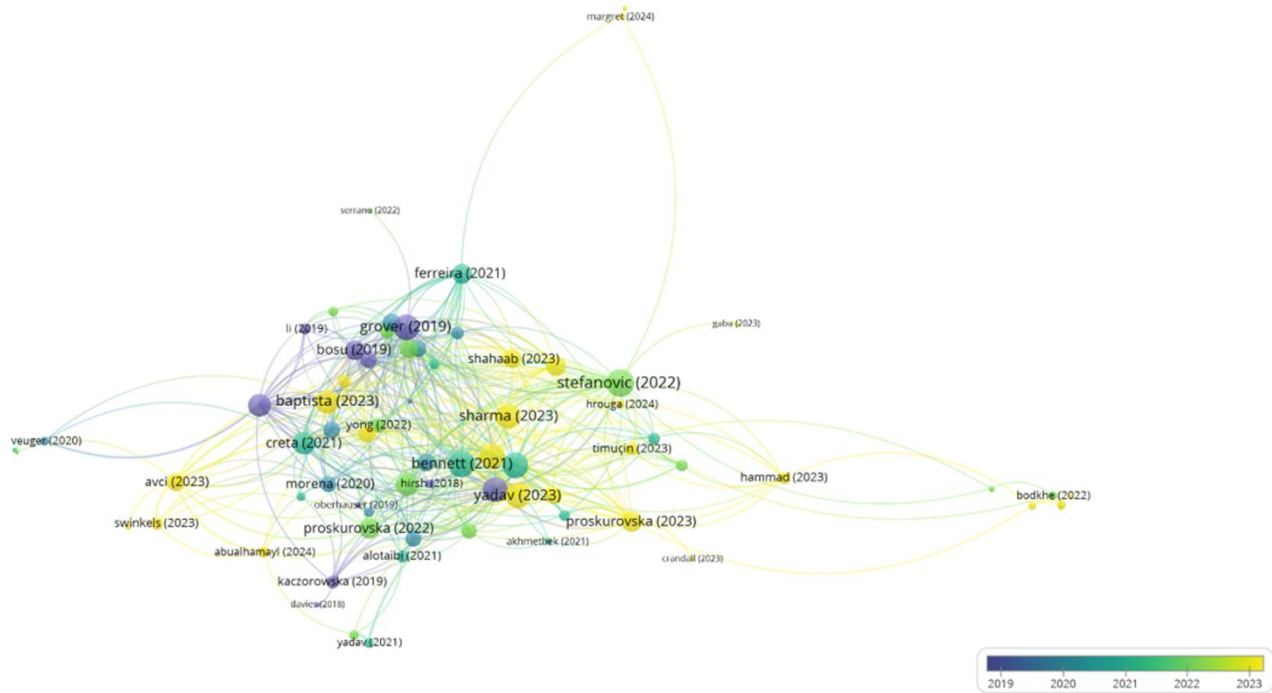


**Figure 7:** Bibliographic Coupling Analysis (total link strength map). VOSviewer.

#### 4.4 Final Sample and Thematic Filtering

A title and abstract screening was then conducted to eliminate irrelevant or redundant articles. The remaining corpus of 58 articles was examined for depth and relevance, and only those offering unique contributions or empirical evidence were retained. This led to a final sample of 40 articles.

These articles were then categorized based on:

- Topic focus (e.g., land administration, tokenization).
- Type of research (e.g., empirical, conceptual, legal analysis).
- Technological frameworks employed (e.g., Ethereum, Hyperledger).
- Geographic focus (e.g., case studies from Sweden, India, Jordan, Cyprus).

This methodology enabled a comprehensive and structured review of the current state of blockchain applications in real estate and laid the foundation for identifying key themes and challenges.

| Stage                         | Description                                                                |
|-------------------------------|----------------------------------------------------------------------------|
| <b>Database Selection</b>     | Scopus database used for literature review.                                |
| <b>Initial Search</b>         | Boolean query returned 481 papers.                                         |
| <b>Screening by Type</b>      | Limited to peer-reviewed journal articles in English; reduced to 121.      |
| <b>Quality Filtering</b>      | Filtered to Q1/Q2 journals based on Scimago; reduced to 40 papers.         |
| <b>Bibliometric Analysis</b>  | Keyword co-occurrence and bibliographic coupling conducted with VOSviewer. |
| <b>Final Sample Selection</b> | 40 high-quality papers categorized for thematic analysis.                  |

**Table 3:** Methodology summary.

## 4.5 Descriptive Analysis

The final corpus of 40 selected articles provided a comprehensive view of how blockchain technology is currently being researched and applied within the real estate domain. The papers spanned a diverse range of topics, reflecting both the versatility of blockchain and the variety of challenges within the real estate sector. A breakdown of the thematic focus revealed the following key areas:

*Land Administration:* 10 articles were dedicated to issues of land registration and property rights management. Approximately half of these proposed new Land Administration Systems (LAS), while the rest focused on enhancing existing systems—often through case studies in specific countries such as Sweden, Serbia, and Bangladesh.

*Tokenization:* At least 8 papers explicitly explored the concept of tokenizing real estate assets, although the topic appeared in some capacity across the majority of the reviewed works. These studies examined models for fractional ownership, smart contract implementation, and the design of token-based investment instruments.

*Smart Cities and Smart Homes:* Around 10% of the sample (4 papers) discussed the integration of blockchain in the context of smart housing systems, including proposals for smart tenancy contracts and urban infrastructure supported by decentralized technologies.

*Digital Real Estate Platforms:* Another 10% of the articles introduced or evaluated blockchain-based platforms for buying, selling, or managing real estate assets, often with emphasis on transparency and automation.

*Legal and Regulatory Challenges:* Four articles provided legal analyses or frameworks aimed at aligning blockchain-based models with existing property law and regulatory requirements.

Methodological Diversity:

*Literature Reviews:* 5 articles offered systematic or narrative reviews of the topic.

*Empirical Studies:* 8 papers involved data-driven research, with 6 relying on surveys and 2 on case-specific field studies.

*Theoretical or Technical Proposals:* The remaining studies presented models, prototypes, or conceptual frameworks for blockchain integration.

*Critical Analyses:* Two papers adopted a socio-economic or ethical lens to assess the implications of blockchain-enabled transformations in real estate.

This range of research perspectives provides a rich foundation for assessing both the current state and future potential of blockchain in the real estate sector. Notably, the corpus reflects a growing interest in combining financial innovation with governance reform, aiming to make real estate markets more inclusive, efficient, and transparent.

| Topic Focus                   | Number of Papers |
|-------------------------------|------------------|
| Land Administration           | 10               |
| Tokenization                  | 8                |
| Smart Cities / Smart Homes    | 4                |
| Digital Real Estate Platforms | 4                |
| Legal and Regulatory Analysis | 4                |

|                                   |   |
|-----------------------------------|---|
| Literature Reviews                | 5 |
| Empirical Studies                 | 8 |
| Technical / Theoretical Proposals | 7 |
| Critical Analyses                 | 2 |

*Table 4: Descriptive analysis summary.*

## 5. Discussion

### 5.1 Key Areas of Focus

#### 5.1.1 Land Administration

Land administration has been one of the most promising domains for blockchain implementation, particularly in terms of improving transparency, reducing fraud, and enhancing efficiency in land registration processes (Zhang et al., 2025; Sladić et al., 2021). Several pilot projects and conceptual frameworks have demonstrated how blockchain can secure land records, offer immutable transaction logs, and streamline bureaucratic workflows.

One of the most frequently cited examples is Sweden's Lantmäteriet agency, which developed a blockchain prototype in collaboration with private firms to enable digital land transactions and reduce the time and paperwork required for ownership transfers (Proskurovska & Dörny, 2022). Similar efforts have been reported in Serbia (Sladić et al., 2021), where blockchain was explored as a verification layer for cadastral and notarial data, and in Bangladesh and India, where blockchain was proposed to combat corruption and record fragmentation in rural property systems (Hasan et al., 2021; Mamun et al., 2021).

Ethereum has been the preferred platform in most of these implementations due to its support for smart contracts and decentralized logic (Zhang et al., 2025). However, permissioned blockchain frameworks like Hyperledger Fabric have been adopted in projects with a strong need for access control and data privacy, especially when dealing with sensitive governmental information (Garcia-Teruel & Simón-Moreno, 2021).

Research suggests that blockchain-based land administration systems can work either as fully autonomous infrastructures or as complementary layers that verify the integrity of existing government-managed registries (Lemieux, 2016). In either case, legal recognition of blockchain records is necessary to achieve enforceability.

#### 5.1.2 Tokenization and Transactions

Tokenization, defined as the process of representing real-world assets on a blockchain in the form of digital tokens, introduces a transformative paradigm in real estate investment and ownership (Avci & Erzurumlu, 2023). By enabling fractional ownership, tokenization lowers investment thresholds, increases market liquidity, and opens real estate markets to a broader set of investors, including those traditionally excluded from high-entry-cost assets (Swinkels, 2023).

Projects such as RealT in the United States demonstrate how tokenized real estate can function as an income-generating and tradable asset, with rental profits distributed automatically through smart contracts. However, as noted by Swinkels (2023), these models often rely on indirect ownership structures (e.g., LLCs), meaning that token holders typically own shares in a legal entity, not the property itself.

To address this limitation, researchers have proposed more robust token structures. For instance, Avci & Erzurumlu (2023) suggest Islamic finance-inspired instruments such as Sukuk, which ensure asset-backing and structured income distribution. Meanwhile, Timuçin & Biroğul (2023) introduce the

concept of Collaborative Smart Contracts (CoSCs) that coordinate interactions between public land registries and blockchain-based transaction platforms, thereby facilitating partial legal integration.

Other frameworks experiment with decentralized governance mechanisms and hybrid consensus models (e.g., Trusted Node Consensus Algorithms), aiming to reconcile decentralized control with the accountability required in land transactions (Garcia-Teruel & Simón-Moreno, 2021). These developments show growing sophistication in technical design but face implementation bottlenecks due to legal and regulatory ambiguity.

## **5.2 Challenges to Integration**

Despite promising developments, full integration of blockchain into the real estate sector faces significant barriers. These challenges can be grouped into two major categories:

### **5.2.1 Legal and Regulatory Hurdles**

Perhaps the most significant barrier to the adoption of blockchain in real estate is the absence of a unified legal framework that formally recognizes tokenized property rights. As Garcia-Teruel & Simón-Moreno (2021) highlight, most jurisdictions still require centralized registries and notarized contracts to define and enforce ownership. Blockchain-based titles, even if technically robust, cannot substitute legally binding records in their current form.

National legal systems differ significantly, both in how they define ownership and in how they treat digital records. This creates a fragmented environment that discourages cross-border innovation and increases regulatory uncertainty (Swinkels, 2023). Furthermore, many pilot projects operate in a legal gray area or rely on sandbox exemptions, making long-term institutional integration difficult.

Data privacy laws, especially in the European Union under GDPR, further complicate blockchain adoption in land systems. Because blockchains are immutable, any storage of personal data—such as ownership records—must be carefully designed to respect privacy rights. Solutions such as off-chain storage or zero-knowledge proofs have been suggested (Avci & Erzurumlu, 2023), but these introduce technical complexity and reduce transparency.

### **5.2.2 Technological and Infrastructural Limitations**

Although not as prominent as legal constraints, technical and infrastructural issues also hinder adoption. Blockchain platforms like Ethereum face scalability and transaction cost challenges, which may render them unsuitable for high-volume or low-cost applications such as national land registries (Yong et al., 2022).

A major issue is the lack of interoperability between blockchain systems and existing governmental IT infrastructure. Legacy systems often rely on outdated formats or proprietary software, making integration with blockchain difficult and costly (Proskurovska & Dörry, 2022). Additionally, many public agencies lack the technical expertise and resources to implement and maintain decentralized infrastructures.

Security is another concern. Bugs in smart contracts, as well as vulnerabilities in wallet infrastructure and oracle services, present substantial risks to both investors and regulators. Several authors note the need for formal verification tools and institutional frameworks for dispute resolution to ensure reliability (Swinkels, 2023).

Lastly, successful integration will require a coordinated approach that combines technological innovation, legal reform, and public-private cooperation (Garcia-Teruel & Simón-Moreno, 2021; Lemieux, 2016). Without alignment among these dimensions, blockchain in real estate will remain limited to pilot projects and isolated use cases.

| Category                        | Issue                                                                            | Future Direction                                                    |
|---------------------------------|----------------------------------------------------------------------------------|---------------------------------------------------------------------|
| <b>Legal Challenges</b>         | Lack of legal recognition for digital property tokens                            | Establish standardized legal frameworks for digital property rights |
|                                 | Divergent national laws and regulatory frameworks                                | Develop cross-border regulatory alignment and cooperation           |
| <b>Technological Challenges</b> | Scalability and privacy limitations                                              | Advance Layer 2 solutions and privacy-preserving protocols          |
|                                 | Interoperability with existing land and property systems                         | Build APIs and middleware to connect blockchain with legacy systems |
| <b>Integration Strategy</b>     | Need for holistic systems linking public registries and private investment tools | Foster interdisciplinary collaboration (law, tech, urban planning)  |

*Table 5: Challenges and future directions.*

## 6. Conclusions

This paper reviewed the current state of blockchain technology integration within the real estate sector, with a particular focus on financial applications such as land administration systems and asset tokenization. By conducting a systematic literature review of 40 high-quality journal articles, we identified key areas of development, technological trends, and ongoing challenges. Our analysis revealed two primary axes of research and innovation:

- The use of blockchain to modernize and secure land registry and property administration systems, particularly in countries with inefficient or corruption-prone infrastructures.
- The deployment of tokenization mechanisms to facilitate fractional ownership, improve liquidity, and broaden investment access in real estate markets.

Although progress has been made in both areas independently, we observed a consistent disconnect between public-sector land systems and private tokenization platforms. This separation reflects a deeper misalignment between technological capabilities and existing legal frameworks. Despite the maturity of many blockchain-based solutions, regulatory uncertainty and institutional rigidity continue to hinder large-scale implementation.

The findings suggest that technological innovation alone is not sufficient. Instead, real transformation in the real estate sector requires coordinated efforts across multiple domains, including law, policy, urban planning, and digital infrastructure. In this context, interdisciplinary collaboration is essential for creating integrated systems that can move beyond proof-of-concept and into practical, legally recognized implementation.

Future research should aim to:

- Develop legal frameworks that support the recognition of digital tokens as valid representations of property ownership,
- Explore hybrid models that combine public infrastructure with private blockchain solutions,
- Leverage complementary technologies such as IoT and AI to enhance smart property ecosystems.

In sum, while blockchain presents a compelling vision for the future of real estate, its successful integration hinges on our ability to align technological, institutional, and legal paradigms—a task that will define the next phase of innovation in the built environment.

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# Organizational subcultures and their influence on information security culture: a qualitative case study

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## Abstract

This study examines how organizational subcultures shape the culture of information security within a company. Focusing on both cultural and policy dimensions, it explores how differing departmental norms, values, and practices influence perceptions and implementation of information security. Using a qualitative case study approach, the research draws on in-depth interviews with employees from multiple departments within a Norwegian IT consultancy company. The findings highlight notable differences in how departments perceive ownership of information security, their levels of knowledge and awareness, and how they prioritize security relative to their specific work goals and operational challenges. These variations underscore the need for flexible, department-specific security measures rather than one-size-fits-all solutions. The study identifies cross-departmental collaboration and knowledge sharing as essential to fostering a cohesive information security culture that aligns with diverse operational needs. The research contributes to a deeper understanding of how subcultural dynamics affect security practices and provides practical recommendations for tailoring policies to better reflect the realities of different organizational units. While limitations such as sample size and participant diversity constrain generalizability, the study offers valuable insights into the interplay between subcultures and information security. Future research is encouraged to further investigate these relationships and assess the long-term organizational impact of adaptive security strategies.

**Keywords:** *Information security culture, organizational subculture, security ownership and awareness, security behavior, security organizational diversity*

## 1. Introduction

This study investigates the cultural and policy dimensions of information systems security within organizations, using a qualitative case study approach. As digital transformation accelerates, modern organizations face increasingly sophisticated cyber threats, driven by rapid advances in technology and the emergence of new methods and tools for cybercrime (Bendovschi, 2015). This evolving threat landscape underscores the growing imperative for security expertise and the implementation of robust, well-integrated security routines (Cram et al., 2017). To address these risks, organizations must formulate information security policies that consider both external and internal threats, including the often-overlooked vulnerabilities that originate from within (Alassaf and Alkhalifah, 2021; Ali et al., 2021).

The human factor has been consistently identified in the literature as a critical vulnerability in information security, with employee actions accounting for the majority of security breaches (Govender et al., 2018; Hustad et al., 2020). Research has shown that employees are frequently the source of security incidents, whether through negligence, lack of awareness, or deliberate misconduct. Accordingly, organizations often implement formal policies, security training, and awareness programs to mitigate these risks and strengthen employee compliance (Ismail, 2022; Alshaikh, 2020). However, mitigating these internal threats requires more than technical fixes or top-down directives—it demands a deeper understanding of the organizational context in which these behaviors occur (Xu and Guo, 2019).

Information systems security encompasses practices aimed at protecting the confidentiality, integrity, and availability of data, as well as the systems, hardware, and processes used to store, process, and transmit it (Kim and Solomon, 2013). Effective security management typically involves a blend of technological controls, formalized procedures, and user education (Whitman et al., 2016; Safa et al., 2019). Yet, despite such efforts, organizations still struggle to achieve consistent compliance and foster a proactive security culture. This challenge is often due to a misalignment between security initiatives and the everyday realities of employees' work environments (Lopes and Oliveira, 2015).

Recognizing information as both a strategic asset and a potential vulnerability, research has increasingly emphasized the value of a socio-technical approach—one that integrates human behavior, organizational values, and technical controls to enhance security culture (Parsons et al., 2014; Pattison et al., 2020). In this context, employee awareness and adherence to security routines are particularly critical, as they represent the frontline defense against both inadvertent and intentional security breaches.

Recent studies have further highlighted the influence of organizational subcultures on information security practices. Da Veiga and Martins (2017) found that distinct subcultures—emerging within departments or workgroups—may diverge from the dominant organizational security culture, leading to varied interpretations and applications of policy. These subcultural dynamics can significantly shape how security is perceived, enacted, and sustained across an organization (Hwang et al., 2021). Understanding these internal variations is essential to designing security frameworks that are both effective and adaptive.

The aim of this paper is to explore how subcultures within an organization influence its overall information security culture. Recognizing the human element as both a vulnerability and a potential strength, the study investigates how departmental cultures affect compliance, perception, and implementation of information security measures. With that aim, the central research question guiding this study is: ***How do subcultures affect information security culture in an organization?***

To answer this question, the study examines various artifacts of information security culture such as practices, policies, routines, and values—across different departments within a single organization. Empirical data is gathered through interviews with employees of a Norwegian IT consulting company. The findings aim to contribute to a deeper understanding of how internal cultural differences influence security behavior and to offer practical insights for enhancing organizational security practices and policies.

## 2. Research background

In this chapter, we review relevant literature on information security (IS) as it relates to this study's focus on how subcultures within organizations influence information security culture. The literature was primarily sourced using the Scopus database, known for its comprehensive indexing of peer-reviewed research. Google Scholar supplemented this process by providing general insights and access to specific articles not readily available through Scopus. The reviewed studies have been categorized into three thematic areas: IS-policy compliance (ISPC) organizational culture and IS-culture, and subculture.

### 2.1. IS-policy compliance

The primary aim of an information security policy is to safeguard the confidentiality, integrity, and availability of information assets (Subramanian et al., 2012). These three pillars ensure that only authorized users access data, the data remains unaltered, and it is available when needed (Lopes and Oliveira, 2015). However, achieving consistent ISPC remains a significant organizational challenge. Studies by Xu and Go (2019) and Siponen et al. (2014) highlight employees' inability or unwillingness to follow established protocols as a persistent issue, influenced by a complex set of individual, cultural, and organizational factors (Safa et al., 2016). Leadership and management support are widely recognized as critical to fostering secure behavior, not through authority alone, but through example-setting, motivation, and guidance (Choi and Song, 2016).

Punitive responses to non-compliance—such as blame or disciplinary action—can backfire, leading to resentment or even deliberate violations of ISP (Cram, 2020; Wall, 2012). Cram et al. (2020) argue that punitive measures erode trust and undermine security culture, whereas proactive managerial involvement, including supportive communication and training, promotes alignment with security goals. Similarly, Wall (2017) cautions that excessive punishment may foster adversarial relationships between staff and management. In line with these concerns, Zheng and Walter (2020) examine how moral intensity and competing values influence compliance behavior. Their model incorporates threat appraisal, coping appraisal, and cost-consequence misalignment—focusing on the cost of compliance to employees versus the consequences of non-compliance for organizations. Their findings emphasize that coping appraisal has a stronger influence on compliance intention than threat appraisal and that factors like proximity and social consensus significantly shape employee-organization dynamics. This suggests that improving relationships between employees and the organization can reduce the moral hazard associated with compliance.

Another major barrier to ISPC is the misalignment between policy requirements and employees' work goals. When policies are viewed as obstacles to productivity, employees may develop workarounds or disregard them entirely (Sadok et al., 2020; Woltjer, 2017). Perceived trade-offs between security and efficiency, safety, or quality further exacerbate this tension (Woltjer, 2017). Recent research advocates for user-centered security designs and adaptive policies that align more closely with real-world workflows and employee expectations (Bada et al., 2019). Together, these insights reinforce the need for security policies that are not only robust but also contextually sensitive and relationship driven.

## 2.2. Organizational culture and information security culture

Organizational culture is shaped by the shared values, beliefs, and norms that influence employee behavior and decision-making (Büschgens et al., 2013). Within this broader context, information security culture (ISC) emerges as a critical subcomponent, reflecting how individuals engage with security policies, practices, and technologies. ISC encompasses both visible and implicit manifestations, attitudes, assumptions, values, and knowledge—that shape security-related behavior (Connolly and Lang, 2012; Ismail, 2022). Rather than relying solely on technical controls, Lopes and Oliveira (2015) emphasize the importance of cultivating a strong ISC through the RITE principles: Responsibility, Integrity, Trust, and Ethicality. These principles promote ethical conduct, personal accountability, and trust, particularly in decentralized or flat organizational structures. Recent research further identifies three key behavioral indicators of ISC—security awareness, security ownership, and security compliance—which provide measurable dimensions for assessing and enhancing security culture (Ismail, 2022; Alshaikh et al., 2021). Together, these cultural and behavioral elements play a foundational role in shaping how employees understand, internalize, and act upon information security expectations.

Security awareness consists of both understanding information security threats and adhering to organizational policies (Rohan et al., 2023). Awareness is often fostered through training programs and regular communication (Govender, Looock & Kritzinger, 2018). Lin and Luo (2021) emphasize the importance of knowledge transfer, particularly around risk identification and threat mitigation strategies. Research also suggests that awareness must be contextual and adaptive to be effective (Parsons et al., 2014; Pattison et al., 2020).

Security ownership describes employees' engagement with an accountability for information security (Ismail, 2022). When employees understand their roles and the consequences of their actions, they are more likely to act securely (Alnatheer et al., 2012). This ownership fosters a proactive security posture across the organization.

As discussed earlier, compliance is shaped by awareness and organizational culture. A healthy ISC promotes security compliance as a normative expectation (Da Veiga and Martins, 2017). Reinforcing the connection between awareness, culture, and compliance is essential for sustainable security behavior.

Even within a unified organizational culture, deviations can occur, leading to the formation of subcultures. Da Veiga and Martins (2017) observed that departments or branches may develop distinct IS subcultures that diverge from the dominant IS culture. These subcultures often reflect differences in professional roles, work environments, or priorities.

Kolkowska (2011) found that subcultures tend to align with organizational divisions, such as functional units or job levels. These cultural distinctions lead to varied interpretations and implementations of IS policies. Value conflicts may emerge, especially when security requirements interfere with departmental work goals.

Understanding these subcultures is essential, as they significantly influence how IS policies are received and acted upon. Subcultures can foster both positive adaptations and dangerous workarounds, depending on how well security practices align with localized needs (Govender et al.,

2018; Loock and Kritzing, 2018; Alshaikh, 2020). Recent studies continue to highlight the importance of recognizing and addressing these internal cultural dynamics (Alshaikh et al., 2021).

### 2.3. Conceptual model

This study employs a conceptual model adapted from Ismail (2022, p.325) as a foundational framework to guide the development of the interview guide and inform the overall research approach. The model conceptualizes *information security culture* through three key behavioral artifacts: *security ownership*, *security awareness*, and *security compliance*. These components collectively form the security culture of information system users, which in turn shapes their *security behavior*.

The model is grounded in the *Theory of Planned Behavior (TPB)*, a well-established psychological framework used to explain human behavior based on attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). In the context of information security, Ismail (2022) applies TPB to illustrate how these cultural artifacts influence users' intentions and actions regarding secure behavior in the workplace. The model posits that increased awareness, stronger ownership, and greater compliance are interconnected elements that directly contribute to positive security behaviors.

By using this model, the study seeks to examine how these factors—when viewed through the lens of departmental subcultures—manifest differently across organizational units. It provides a structured way to explore how variations in knowledge, responsibility, and adherence to policy affect the overall security culture and behavior within a Norwegian IT consultancy firm.

In summary, this chapter has reviewed the key literature surrounding information security policy compliance, organizational and information security culture, and the role of subcultures within organizations. The review highlights that effective information security relies not only on technical measures but also on behavioral and cultural factors, including awareness, ownership, and compliance. Leadership support, alignment of policies with work practices, and user-centered approaches are crucial for fostering secure behavior. Moreover, subcultures—often shaped by departmental roles and priorities—can significantly influence how information security policies are interpreted and enacted. Recognizing and understanding these subcultural dynamics is essential for building a resilient and adaptive security culture. The conceptual model adopted from Ismail (2022), grounded in the TPB, offers a useful framework for examining how these cultural elements manifest across organizational units and shape secure behavior within the context of this study.

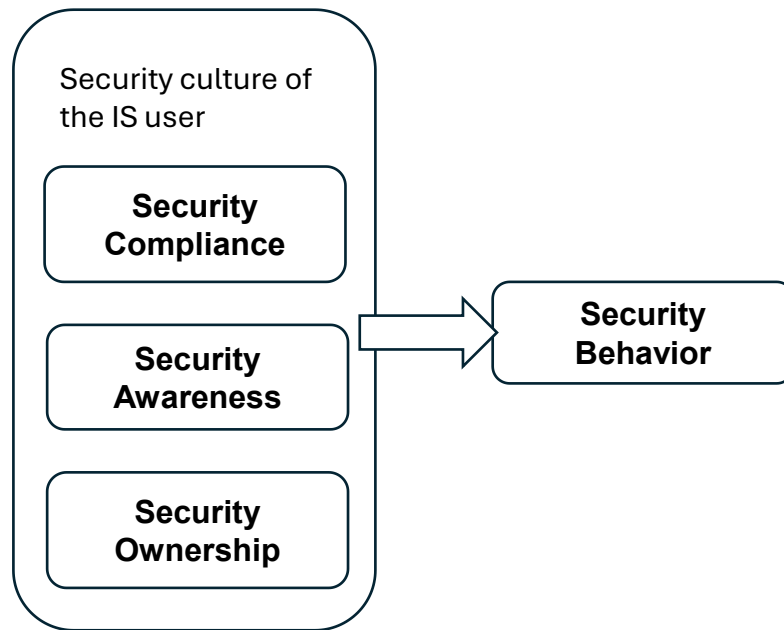


**Figure 1:** Conceptual model of information security culture, its artifacts, and associated behaviors, adapted from Ismail (2022, p.325).

### 3. Research context and methodology

This chapter outlines the research context and methodology encompassing the research design, data collection, and data analysis methods employed in the study.

#### 3.1. Research context

The case company selected for this study is a Norwegian IT consulting firm specializing in delivering case- and archive systems to the public sector, along with consultancy services in Robotic Process Automation (RPA), project management, technical solutions, and privacy services. As a subsidiary of a larger holding company, it operates across multiple locations in Norway and employs approximately 270 professionals. The company was originally part of a larger IT corporation before becoming an independent entity.

The study focuses on employees from three key departments: Sales, Development, and Delivery. These departments differ in their work objectives and approaches to information security, making them suitable for examining how subcultures influence information security culture.

#### 3.2. Research methodology

This research adopts a qualitative case study approach to explore how subcultures develop within different departments and their impact on ISPC. A case study is a methodological approach that involves an in-depth examination of a specific phenomenon, offering insights that contribute to new knowledge and understanding of the research problem (McCombes, 2023; Yin 2003).

The study involved conducting semi-structured interviews to gather data. Interviews are a qualitative method used to explore participants' perceptions, experiences, and insights, particularly in cases where direct observation is insufficient (Hannabus, 1996).

This study is grounded in interpretivism, which emphasizes the subjective experiences and interpretations of individuals (Walsham 2006). Interpretivism is particularly relevant in research that

focuses on human behavior, interactions, and organizational dynamics (Žukauskas et al., 2018). Given that this study seeks to understand employees' perspectives on ISC within their departments, interpretivism provides an appropriate lens.

The study sample was selected with the assistance of a contact person within the organization. The goal was to recruit employees from different departments, preferably those working in the same physical office location to ensure consistency in the organizational context.

The study aimed at getting four participants from each department to participate in the study, resulting in a total of 12 interviewees from the Sales, Development, and Delivery departments. The employees selected for the study held various roles (Table 1).

**Table 1.** *Overview of participants in the study*

| Department  | Role                             | Interview ID |
|-------------|----------------------------------|--------------|
| Sales       | Key Account Manager              | S1           |
|             | Bid Manager                      | S2           |
|             | Customer Manager                 | S3           |
|             | Customer Manager                 | S4           |
| Delivery    | Team Leader for Project Leaders  | DEL1         |
|             | Product Area Manager             | DEL2         |
|             | Team Leader for Technicians      | DEL3         |
|             | Team Leader for Integration Team | DEL4         |
| Development | Chief Developer                  | DEV1         |
|             | Advisor for Development Teams    | DEV2         |
|             | Developer                        | DEV3         |
|             | Junior Developer                 | DEV4         |

The participants' tenure within the organization varied, ranging from employees who had been with the company since its inception to those with only one year of experience. Given the geographical distribution of employees, all interviews were conducted via Microsoft Teams, which facilitated easier scheduling and participation.

To ensure participant comfort and clarity, interviews were conducted in Norwegian, the participants' native language. Transcriptions were later translated into English, ensuring that the original meaning and nuances were retained as accurately as possible.

### 3.2.1. Data collection

Data collection was conducted using semi-structured, dialogue-based interviews, a method that offers both structure and adaptability in qualitative research (Myers and Newman, 2007). This approach allowed for a conversational style of engagement, enabling interviewees to express their views in a

more natural, open-ended manner. Dialogue-based interviews aim to reduce hierarchical distance between interviewer and participant, fostering a more authentic exchange of insights. This was particularly valuable for exploring nuanced aspects of ISC, where individual experiences, departmental norms, and implicit assumptions play a critical role. The interview questions were grounded in the conceptual model proposed by Ismail (2022), targeting key dimensions of ISC such as security awareness, ownership, and compliance. While the interview guide provided a consistent thematic structure, the flexible format encouraged participants to elaborate on their unique perspectives and contexts. This balance between guidance and openness was instrumental in capturing the complexity and diversity of security culture across organizational subcultures.

### 3.2.2. Data analysis

The analysis of interview data was conducted using a qualitative content analysis approach, aimed at identifying thematic patterns across participants' responses. A deductive strategy was employed, guided by the conceptual model proposed by Ismail (2022) and grounded in established principles of **qualitative content analysis**, particularly the structured, theory-driven approach outlined by Zhang and Wildemuth (2009). Deductive content analysis is particularly effective when research is based on a pre-existing theoretical framework, as it enables the systematic classification of data in line with predefined categories (Kvale and Brinkmann, 2009).

The process began with **data preparation**, which included transcribing the audio recordings verbatim and cleaning the transcripts by removing non-essential speech elements—such as filler words, stuttering, and long pauses—to enhance clarity. Units of analysis were then defined, focusing specifically on themes related to security awareness, ownership, and compliance, as outlined in the conceptual framework (Schreier, 2012).

A **coding scheme** was developed based on both the literature and the theoretical constructs of the study. Using a deductive coding approach, predefined categories were used to structure the data, while still allowing for the recognition of new and relevant subthemes as they emerged (Fereday and Muir-Cochrane, 2006). The coding framework was piloted and refined to ensure clarity and applicability across all transcripts (Miles et al., 2014).

To maintain rigor, the coding process was iterative, involving regular verification and cross-checking to minimize researcher bias and enhance consistency. Thematic analysis techniques were also used to synthesize the data and identify meaningful relationships between elements of information security culture and the departmental subcultures within the organization (Braun and Clarke, 2006).

To support the management and analysis of qualitative data, **NVivo** software was employed. NVivo facilitated efficient coding, the visualization of themes, and the exploration of co-occurring concepts, thereby reinforcing the structured application of the deductive framework (Jackson and Bazeley, 2019). The findings were ultimately reported in a structured format, supported by direct quotations from participants to illustrate key themes and strengthen the validity of interpretations.

### 3.3. Evaluation of study

To ensure the rigor and trustworthiness of this interpretive study, the research process followed the seven principles for conducting and evaluating interpretive field studies in information systems, as

outlined by Klein and Myers (1999). These principles provide a comprehensive foundation for evaluating quality in interpretive research, focusing on coherence, plausibility, and theoretical contribution.

The principle of the hermeneutic circle was applied throughout the study by iteratively interpreting the data in light of the broader organizational context and the conceptual model. Understanding developed gradually through cycles of reflection between individual interview accounts and emerging themes, enhancing credibility through depth and contextual sensitivity.

Contextualization was addressed by providing a detailed account of the organizational setting, including relevant cultural, structural, and operational characteristics of the Norwegian IT consultancy firm under study. This enables readers to make informed judgments about the transferability of the findings to other settings. The research process was carefully documented, including design decisions, data collection procedures, and analytic steps supporting transparency (Miles et al., 2014).

Interaction between the researchers and participants was explicitly acknowledged and managed through reflexivity. Researcher preconceptions were critically examined, and participant feedback was incorporated during member checking to enhance the plausibility of the interpretations (Bygstad and Munkvold, 2011)

Abstraction and generalization were addressed by linking empirical insights to the theoretical framework developed from Ismail (2022), moving from specific instances to broader conceptual understanding. Dialogical reasoning was employed to address apparent contradictions in participant narratives and reconcile conflicting views within the analytic process.

Finally, multiple interpretations were considered by comparing and contrasting responses across departments and roles, acknowledging the influence of subcultural perspectives on information security behavior. This approach strengthened the analytical depth and interpretive robustness of the study, while also allowing for the identification of context-specific or idiosyncratic findings (Patton, 2002).

## **4. Findings and analysis**

This chapter presents the findings from the qualitative study, derived from the analysis of the interviews. The results are structured according to the categories outlined in the methodology chapter: *Information Security (IS) Ownership, IS Knowledge and Awareness, and IS Challenges*. Given the focus on department-specific differences, each department is analyzed separately under each section.

### **4.1. Information security ownership**

Information security ownership assesses the level of interest employees have in IS, their understanding of IS concepts, and their prior education or training in IS-related topics.

#### **4.1.1. Delivery Department**

Employees in the Delivery Department demonstrate varied levels of interest in IS, shaped by a combination of personal curiosity and professional responsibility. While most acknowledge the importance of IS, their engagement with the topic ranges from enthusiastic involvement to a more

pragmatic, role-driven approach. One participant expressed a strong personal interest, linking it directly to the nature of the company's operations: "I would say I'm above-average interested in [IS], and I hope the rest of the company is just as interested, considering the kind of business we work in and the systems we deliver" (DEL4).

In contrast, others see IS as essential but not inherently engaging. As one employee noted, "*Neither nor. It's not something I'm very interested in, but it's also very important and can't be ignored*" (DEL3). This perspective reflects a functional mindset—one in which compliance is driven more by necessity than passion.

A likely explanation for these differing attitudes lies in the department's diverse educational and professional backgrounds. Many employees hold managerial positions in non-technical fields, and half of the interviewees have academic training in the social sciences rather than IT or engineering. Nevertheless, there is a strong conceptual grasp of IS responsibilities. As one employee described:

"I think it's a strategy and a set of measures to ensure, at all times, that information is securely stored in line with security and company policies" (DEL2).

Despite the limited presence of formal IS education, all participants reported having received training, certifications, or job-based learning related to information security. This practical exposure fosters a sense of accountability, particularly due to the department's involvement in handling sensitive customer data. Employees were acutely aware of the potential risks posed by data breaches and emphasized the importance of preventive measures:

"The software we deliver must handle and protect sensitive information about people, the company, etc. Having the right tools to ensure information doesn't go astray is the first thing that comes to mind" (DEL1).

Overall, these findings suggest that **information security ownership is relatively strong** within the Delivery Department. While levels of personal interest may vary, this is counterbalanced by a shared sense of professional obligation—driven by the department's critical role in managing customer data and ensuring regulatory compliance.

#### 4.1.2. Sales Department

Compared to the Delivery Department, the Sales Department exhibits a noticeably lower level of engagement with IS. This is likely attributable to the nature of their work, which is more customer-facing and commercially oriented, with minimal involvement in technical systems or backend processes. As a result, IS is often perceived as a peripheral concern rather than a core responsibility.

When asked to describe their understanding of information security, many employees gave brief or vague responses, suggesting limited conceptual depth. One participant remarked, "*I think of passwords, and passwords as a way to prevent unauthorized access, securing our data*" (S1), while another simply noted, "*I think; be a little aware*" (S4). These statements reflect a surface-level engagement, with IS often reduced to a set of basic practices rather than a comprehensive framework for safeguarding organizational assets.

Despite this, there is a general awareness that IS is a necessary part of professional conduct, even if it is not deeply integrated into daily tasks. Notably, one employee stood out for demonstrating a higher level of IS ownership, likely stemming from prior training in security and data protection:

“It is part of my job to ensure things are done properly. And of course, in my daily work, I make sure I don’t mix things up. If security is the big word, then it means I am careful with what I do every day, such as avoiding clicking on unknown links—phishing, viruses, etc.” (S2).

This response illustrates how targeted training, and prior experience can significantly influence individual attitudes toward security, even in departments where IS is not a central function.

Most employees in the Sales Department reported acquiring their IS knowledge through internal training programs, nanolearning modules, and previous work experience rather than formal education or certifications. This informal learning model aligns with the department’s business development role, where security practices are viewed as necessary safeguards but not primary responsibilities. As one participant shared, *“I have IBM courses, nanolearning, our own certification courses, and I’ve been through multiple security courses in my previous jobs”* (S1).

In summary, while **information security is acknowledged as important** within the Sales Department, the level of **ownership and understanding remains limited**. Awareness is generally reactive rather than proactive, shaped more by organizational expectations and basic training than by internalized responsibility. Variability across individuals further highlights the need for tailored approaches to engagement, particularly in departments where technical involvement is minimal.

#### 4.1.3. Development Department

Among the three departments, the Development Department exhibits the highest level of IS ownership. This strong engagement stems from the inherently technical nature of their roles, which involve designing, implementing, and maintaining secure software systems. As a result, IS is not seen as an external obligation but as an integral part of the development process. One developer summarized this mindset clearly:

“Security is something we think about daily—it’s integrated into our work processes” (DEV1).

This daily integration of security into work tasks is reflected in both mindset and practice. Developers are responsible for applying secure coding principles, conducting penetration testing, and ensuring compliance with internal and external security standards. Their responsibilities go beyond following company policy; they also draw on industry best practices and current technical standards to guide their work. As one participant explained, *“Security is part of our job. We work with secure coding practices, penetration testing, and ensuring our solutions meet security requirements”* (DEV3).

Unlike other departments, where IS may be treated as a support function, development staff are **actively engaged in security decision-making** and view themselves as co-stewards of the company’s overall security posture. This high degree of ownership is also supported by their educational backgrounds. Most participants in this group have formal training in cybersecurity or related IT fields, which further reinforces their confidence and capability in managing security risks.

“I have formal training in cybersecurity, and security has always been an integral part of my education and career” (DEV2).

In addition to academic credentials, continuous professional development plays a role in sustaining their engagement. Developers regularly update their knowledge and adapt to new security requirements, aligning both with industry standards and evolving threats.

Overall, the Development Department demonstrates a **proactive and embedded approach to information security ownership**. Security is not viewed as an add-on or compliance task, but as a foundational element of software development. This perspective contrasts with other departments, where ownership tends to be driven by policy compliance or role-based necessity.

#### 4.1.4. Cross-departmental summary of information security ownership

In sum, the findings reveal clear differences in information security ownership across departments, shaped by role-specific duties, technical expertise, and exposure to security training. The Development Department shows high IS ownership due to the direct integration of security into their work. The Delivery Department demonstrates moderate to strong ownership, driven by their responsibility for sensitive customer data. In contrast, the Sales Department exhibits lower ownership, reflecting limited technical involvement but some awareness of professional obligations. These variations underscore that security culture is not uniform but influenced by departmental subcultures that shape engagement, compliance, and attitudes toward IS policies.

## 4.2. Information security knowledge and awareness

This section examines employees' awareness of various risks and threats related to information security, as well as their familiarity with the company's security measures.

### 4.2.1. Delivery Department

Employees in the Delivery Department demonstrate a high level of awareness regarding IS risks, with particular emphasis on threats such as hacking, phishing, and data leakage. These risks are understood not only in generic terms but with nuance, often referring to the diverse forms cyber threats can take. One participant explained, *"Hacking generally, malicious software that gets downloaded. Finding back doors or security holes in digital solutions. Data leakage. Phishing is another threat, or getting asked to give up username and password..."* (DEL2). Another noted the variety of attack types more specifically, stating, *"Well, it could be hacking, hacking of passwords, key logging, machine locking"* (DEL3).

This high level of threat awareness is matched by a solid understanding of internal protocols for responding to incidents. Employees expressed confidence in their knowledge of how to act during a security event and whom to contact. They appeared comfortable navigating the escalation process, which reflects a well-internalized awareness of security routines. As one employee stated, *"I am very aware of what I would do in various situations given what it is. I have a little idea if I discover something that I'm not sure what to do, then I know who to contact, someone who has a security role in the office"* (DEL1). Another added, *"On a level where I can act and notify the right instances"* (DEL4).

While much of the discussion was centered on internal protocols, one participant highlighted the importance of customer-facing security measures, illustrating an understanding of the broader security ecosystem in which the organization operates:

“We do describe in our tender response, we deliver primarily through cloud, and there is a disaster recovery, several backups running that run on a daily basis. That is maybe what you’re looking for. We also have strict regulations for our consultants’ access to our customer data” (DEL2).

This emphasis on both internal and external security practices suggests that the Delivery Department not only recognizes common cyber threats but also understands the layered and interconnected nature of organizational and customer data protection. Their responses reflect a mature awareness of IS, grounded in both policy familiarity and operational relevance.

#### 4.2.2. Sales Department

Employees in the Sales Department exhibit a strong awareness of internal IS threats, particularly concerning the risk of insider misuse. Scenarios involving unfaithful employees—such as those who might sell company data to competitors or leak sensitive customer information—were described in detail, indicating a heightened concern for internal vulnerabilities. This reflects a distinct awareness profile that prioritizes human threats over purely technical ones.

More broadly, participants demonstrated a well-rounded understanding of common security risks, including phishing, data breaches, and malware. One employee explained, *“It’s phishing, when you click on something or are tricked into one or the other, then it’s a type of virus that spreads further and paralyzes the systems internally, also with sharing of data of course...”* (S2). Another reflected both internal and external sources of risk:

“It could be hackers, unfaithful servers, it is mostly those two that often come up. Either hackers attack from outside or malicious attacks from outside, or unfaithful servers internally” (S3).

While awareness of threats was generally high, employees’ familiarity with **internal security measures** and response procedures varied considerably. Some participants were vague or uncertain about how the company would manage a breach or how recovery would be handled. This inconsistency is likely tied to the department’s non-technical role, where employees are not directly involved in implementing security protocols and may instead rely on others for operational support.

Despite these differences, the department benefits from structured awareness initiatives, such as nano-learning modules, which help reinforce core security principles. One employee acknowledged this structure while also admitting to limited technical detail, stating, *“If things go wrong, we have recovery solutions that will get customers up and running quickly. As for our own systems, I assume we have the same thing there”* (S4).

Overall, the Sales Department demonstrates a solid understanding of information security **threats**, especially those stemming from human behavior, but a more fragmented grasp of **response measures** and technical safeguards. Their awareness appears to be shaped more by organizational training than by hands-on experience, emphasizing the need for continued, role-appropriate security education.

#### 4.2.3. Development Department

The Development Department exhibits the highest level of IS awareness among the three departments, a finding consistent with the technical nature of their work. Employees provided in-depth explanations of various security threats—including hacking, phishing, and data leakage—

demonstrating not only familiarity with the concepts but also an understanding of their potential operational and organizational impact. One developer described the severity of unauthorized access in precise terms:

“It’s hacking where one gains access to the systems, authorization, stealing sensitive data. It’s probably those things one fears the most. The fact you can enter a system and pretend to be someone else and execute commands as an administrator” (DEV1).

This advanced understanding is complemented by strong awareness of the organization’s internal security measures. Developers confidently discussed policy implementation and certifications, viewing these frameworks as integral to the company’s security posture. One participant highlighted the organization’s ISO certification as a marker of comprehensive compliance:

“All these systems build up and pull each other forward. As we are ISO certified, I think we cover a lot of important stuff” (DEV2).

An unexpected insight emerged during the interviews, revealing a degree of resistance to specific physical security protocols. One developer questioned the practicality of the mandatory PC-locking policy, noting that office doors are already secured and colleagues are usually present. This led to the perception that some measures might be excessive or redundant:

“We will also lock PCs when we leave them in the office, which does not always get handled because we have locked doors and colleagues are always around, which makes it a silly obligation if you ask me” (DEV1).

This sentiment suggests that even in departments with high security awareness, compliance can be affected by how employees perceive the necessity and relevance of specific policies. Such perceptions may lead to informal rule-bending, especially when policies are seen as misaligned with practical realities.

Another important dimension of the Development Department’s awareness is their understanding of **code-level security**. Developers recognize that maintaining secure coding practices is not a one-time task but a continuous process that must evolve alongside emerging threats and tools. As one participant noted, *“Because people discover new things all the time, and new tools get discovered all the time, so what are the mistakes people make the most when it comes to coding security? Get an update on best practices when it comes to coding security”* (DEV4).

In summary, the Development Department demonstrates a mature and comprehensive understanding of IS risks and responsibilities. Their knowledge is grounded in both technical expertise and practical application, though even here, the perceived relevance of certain policies can influence compliance behaviors. These nuanced views provide insight into how high awareness does not always guarantee universal acceptance of all security measures.

#### **4.2.4. Cross-departmental summary of information security knowledge and awareness**

In summary, the findings reveal clear and meaningful differences in information security awareness across departments, shaped by varying roles, responsibilities, and levels of technical expertise. The Development Department demonstrates the highest level of awareness, underpinned by formal training, direct responsibility for secure coding, and ongoing engagement with emerging security threats and best practices. The Delivery Department also exhibits strong threat awareness, particularly

regarding phishing, hacking, and data leakage, and shows confidence in responding to security incidents—reflecting both practical experience and a clear understanding of internal protocols. In contrast, the Sales Department’s awareness is more focused on internal threats, such as insider misuse, with less consistency in familiarity with organizational security measures. These differences underscore the importance of developing **department-specific security strategies** that align with distinct operational contexts and exposure levels. The next chapter explores how such variations contribute to broader cultural challenges within the organization’s information security environment.

### 4.3. Challenges

This section explores employees’ perceptions of how information security policies impact their work, focusing on work goals and potential challenges. These challenges may stem from individual experiences with IS policies or highlight areas for improvement within the organization’s security framework.

#### 4.3.1. Delivery Department

A strong commitment to achieving organizational objectives is a recurring theme among employees in the Delivery Department. Despite holding managerial roles across various specializations, participants consistently emphasized alignment with the company’s strategic direction—particularly in terms of value creation, stakeholder satisfaction, and successful project implementation. As one participant explained, “They are pretty defined; it is the value of our products. How much income does our work generate for the company, compared to the expenses? Beyond having responsibility over budget, it is also about strategy, objectives, and key results” (DEL2). Another participant added, “I’d like to think I have three things I want to focus on: to create value for myself, for my colleagues, and for the company. I try to contribute to that” (DEL3).

While departmental goals are clear and well-articulated, operational challenges occasionally arise that affect efficiency. Although these do not fundamentally obstruct work goals, they do introduce delays—creating workflow bottlenecks that are especially frustrating in a department that prioritizes responsiveness and performance. Several employees highlighted security-related obstacles that slow down routine operations. One of the most pressing concerns involves customer follow-ups, particularly in accessing and managing customer data. Employees described this process as unclear and inconsistent due to varying interpretations of security permissions.

“It can be challenging in terms of what you are allowed to do—whether you are allowed to log into their account, whether you are allowed to look at their data. It can be challenging because it’s not that black and white...” (DEL1).

In addition, password-related issues surfaced as a frequent source of difficulty. Employees reported struggling with secure and practical methods for sharing credentials with clients.

“Daily challenges tied to passwords and passwords sharing with customers are maybe the challenges we face the most” (DEL3).

Beyond these recurring issues, certain internal security procedures also contribute to inefficiencies. In particular, some tasks—such as approvals or access requests—are dependent on a single employee,

which can result in delays when that individual is unavailable. This "single point of dependency" was frequently mentioned as a workflow bottleneck.

“Some requirements that you must fulfill before moving forward can only be executed by one employee in the company who may not always have the capacity to do it. So, it becomes a ‘stop-and-wait’ situation before we can proceed—essentially bottlenecks and waiting periods” (*DEL4*).

Despite their frustrations, employees acknowledged the rationale behind these controls. There was an overall recognition of the need to balance operational flexibility with data security. As one participant noted, “In some cases, if things could be done in a more flexible way, processes could be faster. But then, they might not necessarily be as safe, and then we are back to customer follow-up (*DEL1*). This tension between security and efficiency is a defining characteristic of the Delivery Department’s experience with information security policy implementation.

#### **4.3.2. Sales Department**

Employees in the Sales Department share a unified set of work goals, primarily centered around generating revenue, achieving sales targets, and maintaining strong relationships with clients and partners. Their efforts are directed at ensuring the consistent delivery of high-quality products and timely services, with the ultimate aim of boosting customer satisfaction and fostering long-term business growth. As one participant explained, “My work goals are to ensure that we have enough missions for the company through the sales of products we offer. It revolves around being in contact with customers and partners to ensure business. Work that creates income” (*S1*).

Compared to other departments, the Sales team reports fewer challenges related to information security policies. Nevertheless, one notable issue emerged during the interviews: the classification of documents. Employees are responsible for determining whether documents should be labeled as public or private, and in some cases, applying more sensitive classifications such as "secret" or "top secret." This system often creates ambiguity and hesitation. One employee elaborated:

“I would say it is a little challenging with the categorization of documents—whether they should be classified as public or private. Some codes are a bit difficult to use. Should I use this code or that one? Using the wrong code feels horrible if something is meant to be limited” (*S3*).

This uncertainty illustrates a knowledge gap that, while not obstructive to daily operations, may pose a potential risk if misclassifications occur. Still, aside from this challenge, Sales employees generally perceive security routines as unobtrusive and appropriate for their work context. As another participant put it, “No, they don’t (routines). It is a completely normal and suitable level for what we work with and my customer group, private and public” (*S1*).

Given that the department’s operations are less technical in nature, the limited friction between work goals and security practices is unsurprising. The security protocols in place appear to be sufficiently aligned with the department’s focus on relationship management and revenue generation, contributing to a relatively smooth integration of security measures into everyday tasks.

### 4.3.3. Development Department

The Development Department focuses on software development, efficiency, and quality as its core work objectives. Employees aim to refine their technical skills and problem-solving capabilities while meeting customer expectations, often adapting their priorities in response to project demands. One developer summarized this mindset: “The most important thing I think about is development, efficiency, and quality. When you have worked with a product for so long, you develop a gut feeling about what to do and what not to do” (*DEV2*).

While the department generally embraces the organization's security posture, one recurring point of contention is the screen-locking policy. Developers are required to lock their screens whenever stepping away from their desks—a policy perceived by some as redundant, especially given existing physical access restrictions within the office. This has led to a sense of irritation and, at times, disengagement with broader security practices.

“One can become negative and ignore these guidelines or commands. If another regulation comes along and you are already irritated over an existing one that you find unnecessary, you might start ignoring those orders. I think it’s a bit unnecessary” (*DEV1*).

This sentiment illustrates how even well-intentioned policies can backfire when they are seen as intrusive or misaligned with the practical realities of technical work. Despite such frustrations, employees in the Development Department generally express satisfaction with the organization's ongoing investment in information security. There is clear recognition that the company has made meaningful efforts to improve its security measures and practices in recent years.

“We’ve had some students in the office who were able to identify certain vulnerabilities through testing. Some of the reports we’ve ordered don’t include everything, but I know there has been an increased focus on hiring people with that type of responsibility. So, I can’t complain about it when I see that things are being addressed” (*DEV4*).

This appreciation for proactive efforts—such as bringing in interns to test vulnerabilities—reflects a mature perspective on security, where criticism of specific policies coexists with recognition of broader progress. The Development Department’s feedback underscores the importance of involving technical teams in shaping security protocols that are both robust and realistic.

### 4.3.4. Cross-departmental summary of identified challenges

In summary, the findings reveal distinct, department-specific challenges in implementing information security policies, reflecting the varied work practices and cultural orientations within each unit. In the Delivery Department, operational efficiency is hindered by delays related to customer follow-ups and difficulties with secure password-sharing protocols. In the Sales Department, employees primarily struggle with document categorization, although most do not perceive broader security policies as disruptive to their work routines. Meanwhile, the Development Department expresses frustration with specific measures—such as mandatory screen-locking—that are seen as misaligned with daily workflows, despite a general appreciation for the company’s increased focus on security.

These differences reflect more than just practical challenges; they reveal the presence of **departmental subcultures**—shared norms, values, and priorities that shape how employees engage with and interpret security policies. Such subcultures influence perceptions of relevance, necessity,

and burden when it comes to compliance, highlighting that a one-size-fits-all approach may be insufficient. Collectively, these insights underscore the importance of aligning security requirements not only with technical processes but also with the cultural and operational realities of each department, ensuring that policies enable rather than obstruct secure and efficient work.

## 5. Discussion and implications

This chapter analyzes the interview findings considering existing literature and the conceptual model developed by Ismail (2022), which frames IS culture through three key behavioral artifacts: security ownership, awareness, and compliance, all of which collectively shape security behavior. The discussion is structured around these dimensions, concluding with implications for research and practice, study limitations, and directions for future work.

### 5.1. Information security ownership

The findings reveal significant variation in how employees across departments perceive and assume responsibility for information security. These differences align with the "security ownership" component of Ismail's model, which refers to the degree to which employees internalize responsibility for secure behavior.

In the *Development Department*, IS ownership was strongest. Employees demonstrated high levels of engagement, rooted in both formal training and direct involvement in secure coding, system testing, and technical implementation. This group often viewed security as a natural extension of their professional identity. These findings are consistent with prior work by Alnatheer et al. (2012) and Ismail (2022), who argue that technical expertise and role alignment play a critical role in fostering a strong sense of security ownership.

The *Delivery Department* showed moderate to strong ownership. While their roles were less technical, their responsibility for customer data and compliance gave rise to a practical understanding of IS and a willingness to take ownership. Here, professional obligation rather than personal interest seemed to drive secure behavioral trend supported by Cram et al. (2020), who emphasize the role of management expectations and task relevance in shaping compliance.

In contrast, the *Sales Department* exhibited lower levels of security ownership. Most employees viewed IS as important but tangential to their core responsibilities. Their engagement was generally passive, shaped more by organizational rules than personal initiative—echoing findings from Ali et al. (2021) and Ismail (2022), who note that non-technical staff often view IS as "someone else's job."

These variations illustrate that IS ownership is not uniform but is influenced by departmental subcultures—shared norms, values, and expectations that emerge within specific work units (Da Veiga & Martins, 2017). While not explicitly mentioned by participants, the presence of these subcultures is reflected in how each department prioritizes and engages in security. This supports Kolkowska's (2011) findings on value conflicts and distinct IS subcultures within organizations.

### 5.2. Information security knowledge and awareness

All departments demonstrated baseline awareness of IS threats and protocols, but the depth and nature of this awareness varied substantially mirroring the "security awareness" layer in Ismail's model.

The *Development Department* again stood out with the highest awareness. Employees discussed specific threats such as phishing, malware, and privilege escalation, and emphasized continuous learning through formal training and hands-on practice. This aligns with the importance of ongoing professional development highlighted by Rohan et al. (2023) and Hwang et al. (2021) and reflects the type of technical engagement that fosters deep awareness (Parsons et al., 2014).

The *Delivery Department* showed strong practical awareness, particularly around threat response and data protection. Employees were confident in knowing who to contact and how to act during incidents, which may stem from their managerial roles and customer accountability. This supports findings by Hustad et al. (2020), who argue that operational responsibility often enhances situational awareness.

In contrast, awareness in the *Sales Department* was more fragmented. While some employees mentioned phishing or insider threats, their familiarity with broader security protocols was inconsistent. Most knowledge stemmed from internal nano-learning modules, rather than experience or formal education. This supports Bada et al. (2019), who caution that awareness campaigns often fail to translate into behavioral change if not contextually relevant.

The role of subcultures is again evident here. Development employees engage deeply with security because their subculture emphasizes technical mastery and system integrity. In contrast, the Sales Department's focus on customer relationships creates a culture where security is seen as supportive but not central. These internal cultural dynamics highlight the need for department-specific training strategies (Govender et al., 2018).

### 5.3. Information security challenges

All departments face challenges in implementing IS policies, yet the nature of these challenges reflects differences in workflows, priorities, and departmental subcultures—fitting within the compliance and behavioral context of Ismail's model.

The *Delivery Department* reported delays caused by complex protocols for accessing customer data and password sharing. These procedural obstacles, while rooted in compliance, often clashed with their need for workflow efficiency. As Woltjer (2017) and Sadok et al. (2020) argue, when security measures conflict with productivity, workarounds and non-compliance may emerge.

The *Sales Department*, by contrast, found document classification requirements challenging, citing ambiguity in categorization systems. However, they did not perceive most security measures as disruptive—likely due to their minimal engagement with technical systems.

In the *Development Department*, frustration arose over mandatory security routines such as screen-locking. These policies, although necessary from a governance perspective, were seen by some as inefficient or excessive, particularly in secured office settings. This aligns with findings by Subramanian et al. (2012) and Xu and Guo (2019), who highlight how perceived misalignment between policy and task relevance can reduce compliance motivation.

Crucially, these challenges underscore the impact of IS subcultures—not only in shaping attitudes but also in mediating resistance or acceptance of security policies. Kolkowska (2011) and Da Veiga and Martins (2017) argue that such subcultures can either reinforce or weaken organizational IS culture, depending on how well policies align with local norms and expectations. In this study,

subcultures helped explain why the same policies were embraced in one department and resisted in another.

#### 5.4. Integrating subculture into Ismail's model

While Ismail's (2022) conceptual model effectively captures the behavioral artifacts that influence IS culture—ownership, awareness, and compliance—the findings of this study suggest an important extension: the influence of subculture as a contextual layer that shapes how these artifacts manifest across departments.

As shown in Figure 1, the three components are interconnected and collectively shape security behavior. However, departmental subcultures moderate these relationships, influencing the extent to which ownership is felt, awareness is internalized, and compliance is enacted. In line with Büschgens et al. (2013), who emphasize the interplay between organizational culture and innovation, this study highlights that IS culture should not be viewed as monolithic. Instead, it must be understood as fragmented and context-dependent, with subcultures exerting a powerful influence on behavior and policy interpretation (Figure 2).

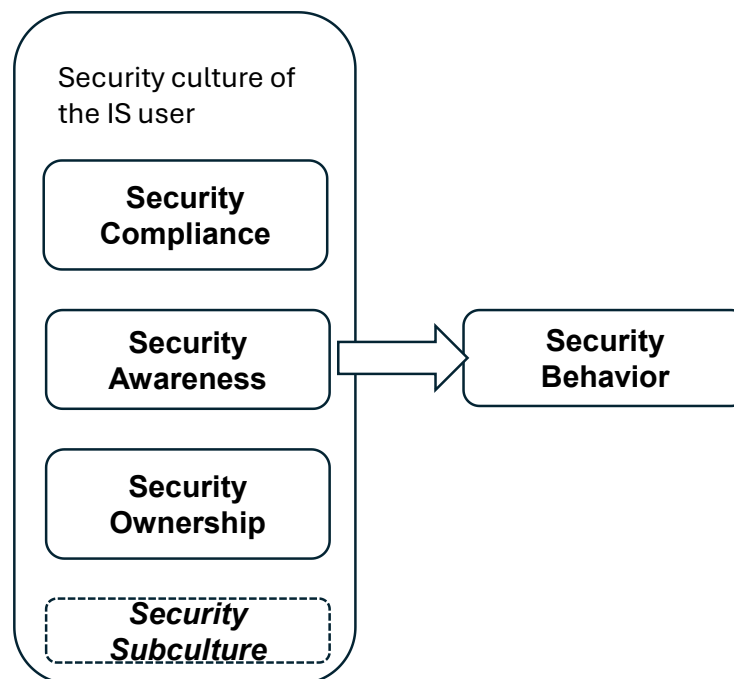


**Figure 2:** Extended conceptual model with “security subculture,” based on Ismail (2022).

#### 5.5. Implications for practice

The findings of this study underscore the importance of tailored information security practices across organizational departments. The observed variation in levels of engagement, ownership, and awareness highlights the need for department-specific policies, routines, and training initiatives. A one-size-fits-all approach to information security may fail to address the unique needs and work practices of different units. Instead, a customized strategy can promote stronger compliance and foster a greater sense of responsibility among employees (Ismail, 2022; Alshaikh, 2020).

Encouraging interdepartmental collaboration and knowledge-sharing is also vital. Facilitating dialogue between departments can bridge technical knowledge gaps and support the integration of security into diverse operational contexts. When employees share practical experiences and best

practices, they contribute to a more cohesive and adaptive security culture. This approach aligns with findings by Govender et al. (2018), who emphasize the role of peer learning in cultivating security awareness.

Moreover, organizations must ensure flexibility and responsiveness in their security policies. Recognizing the specific constraints and workflows of each department allows security measures to be both effective and minimally disruptive. Implementing feedback mechanisms—such as regular evaluations or user-centered design principles—can help adjust policies in response to evolving needs, aligning security objectives with broader organizational goals (Woltjer, 2017; Bada et al., 2019).

Ultimately, these measures can strengthen both policy compliance and cultural alignment, reduce security-related friction in daily tasks, and foster a more security-conscious workforce—contributing to reduced risk exposure and improved protection of sensitive information.

### **5.6. Implications for research**

This study contributes to the growing body of literature emphasizing the influence of organizational subcultures on information security behavior. By examining how different departments develop distinct security priorities, values, and engagement levels, the findings offer important insight into how subcultural dynamics shape compliance, awareness, and ownership (Da Veiga & Martins, 2017; Kolkowska, 2011). Future research should explore these subcultural variations more explicitly, perhaps through comparative case studies or longitudinal designs.

The study also advances research on the alignment between security measures and operational workflows. A recurring theme across departments was the tension between security protocols and work efficiency. Identifying and addressing these misalignments is crucial for improving policy effectiveness. These findings reinforce calls by Subramanian et al. (2012) and Sadok et al. (2020) to integrate security practices more seamlessly into employees' day-to-day tasks.

Furthermore, this research supports a more nuanced view of security culture, suggesting it is not a monolithic organizational trait but rather a layered construct influenced by both formal structures and localized subcultures. Expanding Ismail's (2022) model to include security subculture as a mediating context offers a valuable direction for future theoretical development.

Taken together, these insights open new avenues for research that bridges organizational behavior, cybersecurity, and workplace designing the groundwork for more adaptive and context-sensitive information security strategies.

### **5.7. Limitations**

Several limitations should be acknowledged when interpreting the findings of this study. First, participant selection was managed by a contact person within the organization, which limited the researcher's control over sampling and may have introduced selection bias. While efforts were made to include four employees from each department, a randomized or more demographically diverse sample could have yielded broader perspectives.

Second, the small sample size limits the generalizability of the results. Though qualitative studies aim for depth rather than breadth, the limited number of participants may not fully capture the diversity of views within each department. Moreover, variability across office locations, including differences

in team structures, resource availability, and local culture—could influence information security practices in ways not fully explored in this study.

Third, participants had varying levels of tenure, ranging from recent hires to long-standing employees, including some who had transitioned from a prior organizational structure. These differences may have shaped their understanding of and attitudes toward information security, potentially influencing how they interpreted and responded to policy measures.

Finally, all participants from the Delivery Department held managerial positions, which may have skewed the findings toward leadership perspectives. As a result, the views and experiences of non-managerial employees—who may face different practical challenges—are underrepresented in that department.

### **5.8. Future research**

Future research should further explore the role of organizational subcultures in shaping information security culture. This study found that departments exhibited distinct attitudes, practices, and challenges, suggesting that subcultures play a critical role in shaping security behavior. More detailed investigations into these subcultural dynamics can help organizations develop more nuanced, context-specific security strategies (Kolkowska, 2011; Da Veiga & Martins, 2017).

To strengthen generalizability, future studies should employ larger and more diverse samples, potentially combining qualitative and quantitative methods. Mixed-methods approaches could provide deeper insight into both the behavioral and statistical dimensions of security compliance and awareness (Fereday & Muir-Cochrane, 2006).

Additionally, future research should consider more granular departmental categorizations, particularly in functionally complex units such as software development teams. As observed in this study, even within one department, sub-teams may differ significantly in terms of responsibilities and technical exposure.

Another promising direction involves investigating the alignment (or misalignment) between security policies and operational workflows. Identifying specific areas of friction can help organizations design security practices that are both effective and minimally disruptive, contributing to improved compliance and productivity (Woltjer, 2017; Sadok et al., 2020).

Finally, longitudinal research is needed to assess the long-term impact of security policies on organizational performance, employee satisfaction, and cultural change. Such studies could illuminate how sustained exposure to security routines influences attitudes and behaviors over time, providing valuable insights for policy development and organizational change management.

## **6. Conclusions**

This study explored how organizational subcultures influence information security culture, focusing on variations in security ownership, awareness, knowledge, and the practical challenges experienced across departments. The findings reveal both shared values and distinct differences in how employees engage with security, shaped by factors such as technical expertise, managerial responsibility, and customer-facing roles.

A key insight is the need to balance security policies with operational realities. Across departments, participants identified tensions between formal security routines and the demands of daily work. These challenges underscore the importance of designing security practices that are both effective and adaptable to departmental workflows.

Although subcultures were not directly addressed by participants, the clear departmental differences in attitudes, behaviors, and compliance indicate the implicit presence of security subcultures—distinct sets of norms and expectations that shape how security is understood and practiced. This supports prior research emphasizing the fragmented nature of organizational culture in the context of information security (Kolkowska, 2011; Da Veiga & Martins, 2017).

While the study is limited by its small sample size and purposive participant selection, it provides valuable empirical insights into the interplay between organizational culture, departmental subgroups, and information security behavior. These findings contribute to the broader discourse on how cultural context shapes security engagement and highlight the value of a subcultural lens in both research and practice.

Future research should expand on these insights by further examining the role of subcultures, exploring larger and more diverse samples, and assessing the long-term impact of security initiatives across organizational units.

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# **The Impact of Autonomous Taxation on Corporate Income Tax Payable – The Case of the 100 Best Companies in the District of Leiria**

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## **Abstract**

The Portuguese tax system is characterized by increasing complexity, resulting from continuous legislative developments and the State's efforts to combat tax evasion and abusive tax planning. In this context, autonomous taxation (AT) emerges as a unique mechanism that applies not to the company's taxable income, but to specific expenses or charges considered to deviate from the normal scope of business activity. Since its introduction in 1990 through Decree-Law No. 192/90, AT has become a central instrument for increasing tax revenues while reinforcing the dissuasive function of tax policy. This study aims to analyze the impact of AT on corporate income tax (IRC) payable by the 100 best companies in the district of Leiria, examining its relative weight, evolutionary trend, and differences compared to the national landscape.

Autonomous taxation is levied on several types of expenses, including undocumented costs, travel allowances, payments to managers, car-related expenses, and representation costs. Article 88 of the Corporate Income Tax Code (CIRC), which governs AT, has undergone multiple legislative changes, reflecting the legislator's efforts to adjust to evolving economic realities and business behavior. The doctrine identifies multiple purposes for AT: it serves as a sanctioning measure, an anti-abuse mechanism, and is even interpreted by some as a form of indirect taxation on expenses. Constitutional jurisprudence has affirmed its distinct material nature and role in preventing practices that undermine the fairness and efficiency of the tax system.

This study is based on a sample of 96 companies selected from the annual ranking published by the Região de Leiria newspaper, which identifies the region's top-performing companies according to financial and operational indicators. Four companies were excluded due to missing or inconsistent data. Financial information was obtained from the SABI (Iberian Balance Sheet Analysis System) database, covering the years from 2019 to 2022. This period was chosen to capture pre-pandemic, pandemic, and post-pandemic economic cycles and their influence on corporate taxation.

The research confirms that autonomous taxation imposes a significant fiscal burden on companies and that effective management of these expenses can contribute to tax optimization. While this study did not analyze each type of AT charge individually, the data suggests that vehicle-related costs and representation expenses are among the most common triggers. Furthermore, legislation imposes higher AT rates on companies with tax losses, potentially worsening the financial condition of struggling firms and raising concerns about tax equity. Based on the findings, further research is recommended in three directions: (1) a breakdown of the AT burden by type of expense, to identify the most impactful charges; (2) geographic extension of the study to other districts for comparative analysis; and (3) in-depth sectoral studies to assess the variability of AT across different industries.

Such analyses would contribute to a more comprehensive understanding of AT's role in Portuguese corporate taxation and support the design of more targeted fiscal policies.

In conclusion, this study demonstrates that autonomous taxation remains a significant factor in companies' overall tax liabilities. Proper awareness and management of AT can be critical for the financial health and strategic planning of businesses. The case of companies in the district of Leiria shows that local dynamics can diverge considerably from national trends, highlighting the need for more granular and contextualized fiscal analysis in Portugal.

**Keywords:** *Autonomous Taxation, Corporate Income Tax, Taxation, Companies, Leiria, Fiscal Management, Tax Policy*

# **Modernizing financial crime enforcement: legal foundations, digital integration and audit practice in the Greek financial and economic crime unit (SDOE)**

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## **Abstract**

This paper provides an in-depth examination of the legal and operational architecture of the Financial and Economic Crime Unit (SDOE) in Greece, a central institutional actor in the prevention, detection, and prosecution of financial crime. Anchored in a complex legislative framework, the study explores the SDOE's organizational structure, audit procedures, jurisdictional competencies, and inter-institutional cooperation mechanisms. Special attention is devoted to the evolving role of digital evidence - particularly social media - in enhancing the effectiveness and scope of financial investigations. The analysis integrates legal perspectives on data protection and the General Data Protection Regulation (GDPR), examining the balance between investigative necessity and individual privacy rights. The study also outlines strategic policy recommendations, including the codification of digital evidence practices, enhanced interoperability, and capacity-building in digital forensics. By synthesizing legal theory with applied audit methodology, the paper underscores the imperative for a technologically adaptive and legally robust enforcement model capable of addressing the multifaceted challenges of economic criminality in a digitized global environment.

**Keywords:** *Money Laundering, Tax Evasion, GDPR, Social Media*

## **1. Introduction**

The General Directorate for Financial and Economic Crime Unit (SDOE) constitutes an autonomous and specialized enforcement mechanism, which has emerged as a critical institutional actor in the fight against financial crime, tax evasion, and fraud against the public interest. The operational activities of the SDOE are governed by a multifaceted legal framework that delineates its

administrative structure, its mandate, and the procedural mechanisms for conducting audits and investigations.

The legislative and regulatory corpus underpinning the SDOE's functions comprises a broad array of statutory provisions, including Laws: 3296/2004, 3691/2008, 4557/2018, 3446/2006, 4313/2014, 2690/1999, 4490/2017, 4144/2013, 4496/2017, Joint Ministerial Decision 45231/2017, as well as Law 2121/1993, Law 4155/2013, Law 4410/2016, Law 4622/2019, and Presidential Decrees 142/2017, 84/2019, and 85/2005. Furthermore, the audit procedures executed by SDOE officers are subject to the general provisions of the Code of Criminal Procedure, particularly Article 31, which regulates the preliminary examination phase of criminal investigations.

This article tries to present a comprehensive overview of the institutional configuration of the SDOE, its operational methodology in audits, and the broader procedural architecture within which its investigative functions are embedded, with a view to elucidating the organization's role in safeguarding public revenue and financial transparency.

Economic crime in Greece is multifaceted, encompassing tax evasion, money laundering, fraud, and corruption. These crimes severely impact fiscal stability and public trust. Greece's shadow economy is one of the largest in the EU, exacerbating revenue losses and public sector inefficiency (Vlachos & Bitzenis, 2015).

The Greek financial crisis further revealed weaknesses in public administration and exposed systemic tax evasion and illicit financial flows. SDOE has been central to uncovering such crimes through investigations involving banking secrecy breaches and asset tracking (Saranti et al., 2017).

Tax evasion and tax avoidance are persistent challenges in Greece, deeply rooted in its economic and institutional structures. While tax avoidance exploits legal ambiguities, tax evasion blatantly violates tax legislation. The normalization of these practices has significantly undermined the fiscal stability, public confidence and economic development of the state. The SDOE of Greece plays a critical role in addressing these issues, particularly in line with the international standards set by the Financial Action Task Force (FATF).

Tax avoidance is a legal way for taxpayers to avoid paying excessive taxes and reduce their tax liability to the state. However, tax avoidance can be considered illegal when taxpayers deliberately and fraudulently ignore tax laws for their own benefit and wealth.

Tax evasion in Greece is closely linked to a large informal economy and weak institutional frameworks, as an illegal act. One study suggests that reforms often fail because they underestimate structural resistance and overestimate behavioral change, such as changes in tax morale. One solution is to tax only wealth (e.g. real estate and financial assets), while simultaneously abolishing income and value-added taxes to improve compliance and efficiency (Papanikos, 2015). Despite improvements in the audit infrastructure, frequent changes in tax laws have historically undermined enforcement consistency and public compliance. Studies show that legal instability generates perceptions of unfairness and unpredictability, which weaken voluntary compliance (Heinemann & Kocher, 2013). Furthermore, tax compliance is found to be path-dependent, influenced by previous enforcement experiences—suggesting that reform inconsistency can erode long-term trust in institutions (Bruttel & Friehe, 2010). Finally, the emphasis on reactive, revenue-driven enforcement rather than predictable and stable policy reform has been shown to damage compliance culture over time (Feria, 2020).

Greece's tax evasion problem is both systemic and psychological. Empirical research shows that Greek citizens tend to justify tax evasion not primarily for personal gain, but due to a widespread distrust in the state's ability to fairly and efficiently allocate public funds (Drogalas et al., 2018). This attitude is compounded by perceived corruption, legal overregulation, and inefficiency, which collectively erode tax ethics. According to Vousinas (2019), the shadow economy accounts for a

substantial portion of Greece's GDP, further indicating how deeply rooted non-compliance is within the broader economic culture.

The Greek financial system has also experienced a variety of sophisticated fraud schemes. A study of commercial banks identified forgeries, bribery, and money laundering as prevalent forms of economic crime. Methods include the use of dormant accounts, forged signatures, and identity theft (Repousis et al., 2019). These schemes often blend avoidance and evasion tactics, exploiting regulatory gaps and weak internal controls.

Greece has fully aligned with EU directives, criminalizing tax evasion as a predicate offence for money laundering and has made significant strides in improving law enforcement through digitalization, inter-agency cooperation and alignment with FATF standards. Law enforcement agencies, following the guidelines for the Fight against Money Laundering, are transparent and direct in their investigation of persons involved in cases that show a strange increase in assets.

Within this framework, the SDOE, as one of the audit services for the suppression of economic crime and delinquency, cooperates with financial institutions to monitor suspicious transactions and report them to the Hellenic Financial Intelligence Unit (FIU).

In order to uncover illegal asset flows or asset increases, the SDOE resorts to collecting and extracting data from banking institutions' databases for cross-checking and inconsistency with declared income. In the case of financial fraud, the SDOE can proceed with the seizure of assets: Legal reforms have reduced the duration of asset liquidation in tax fraud cases - from three years to three months - optimizing deterrent measures.

Although Greece has laws to protect whistleblowers, their implementation remains weak. Whistleblowers often lack anonymity and institutional support, resulting in underreporting of corruption and fraud. The lack of a formal, incentivized whistleblower protection system hinders internal disclosures within the public and private sectors (Repousis et al., 2019).

Such methods have proven effective when direct evidence is lacking, especially for high net worth individuals and politically exposed persons.

As digital technologies reshape modern policing, social media platforms like Facebook Instagram and Tik-Tok have emerged as powerful tools for intelligence and investigation. Law enforcement agencies globally are embracing Social Media Intelligence (SOCMINT) to identify and investigate crimes, monitor public behavior, and collect evidence. Social media has transformed from a means of casual interaction to a rich source of criminal intelligence. Globally, law enforcements have integrated social media into intelligence-led policing practices, using it to locate suspects, identify criminal networks, and gather digital evidence. Platforms provide both retrospective and real-time information, aiding investigations into the planning, execution, and aftermath of criminal acts (Fortin et al., 2021). In Greece, the SDOE increasingly leverages these tools to monitor digital footprints and cross-reference lifestyle indicators with declared income, exposing hidden assets and potential tax fraud. This practice helps identify discrepancies in undeclared wealth or fraudulent activity patterns.

The SDOE has made meaningful strides in combating economic crime in Greece through asset-focused audits, legal reforms, and increased cooperation with financial institutions. However, systemic tax evasion, weak whistleblower systems, and the need for technological modernization continue to challenge enforcement efforts. Embracing digital tools, expanding indirect audit capacity, and fostering public trust through transparency and protection mechanisms are vital for long-term effectiveness.

## 2. Institutional Framework: Organization and Competencies of the SDOE

Operating under the auspices of the Ministry of National Economy and Finance, the Financial and Economic Crime Unit (SDOE) is strategically organized to optimize the detection, investigation, and prosecution of economic and financial crimes. Its administrative configuration includes a central service headquartered in Athens, supplemented by a regional branch in Thessaloniki. The structural organization of SDOE is both geographically and thematically segmented, ensuring comprehensive oversight across diverse domains of economic criminality.

The central service bears responsibility for the formulation of strategic objectives, coordination of operational design, and facilitation of both national and international interagency collaboration. In contrast, the regional services undertake the implementation of field audits, local inspections, and region-specific investigations.

Moreover, the agency is supported by specialized departments that focus on particular typologies of financial misconduct, such as economic crimes, corruption of public officials, smuggling operations, and risk analysis. This diversified and hierarchical organizational scheme allows SDOE to maintain adaptive capabilities in addressing complex and evolving forms of financial malfeasance.

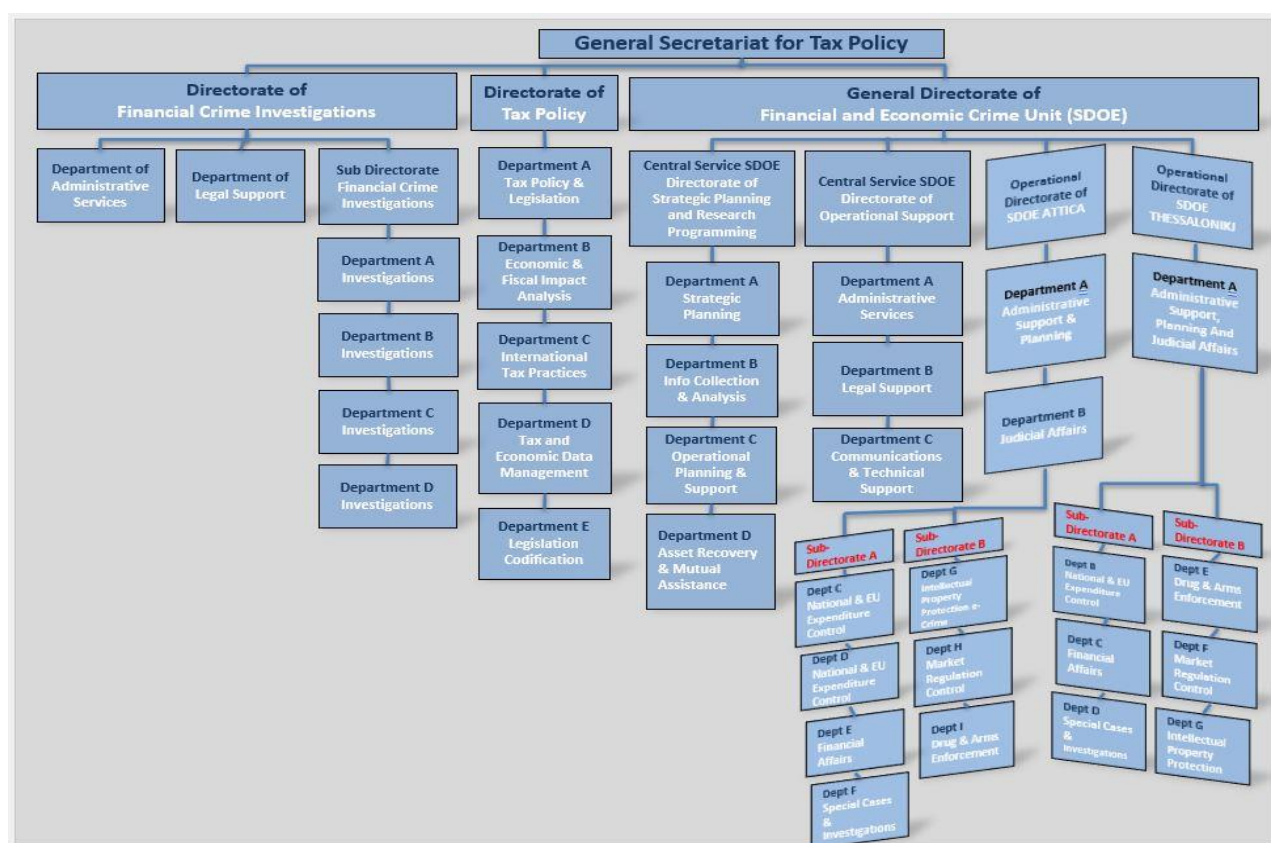


*Figure 1: Organizational Chart- General Secretariat for Tax Policy (2025).*

### Main Responsibilities

The SDOE is entrusted with the investigative and prosecutorial responsibilities pertaining to various economic infractions, including tax evasion, fraud, smuggling, corruption, and money laundering. The agency conducts audits on both natural and legal persons to identify and document financial violations. Its operational efficiency is enhanced by access to a wide spectrum of national and international databases, partnerships with financial institutions, and a robust mechanism for citizen-submitted complaints via online platforms and electronic communication. As Korontzis (2012)

highlights, the SDOE plays a pivotal role within the Greek prosecutorial framework for economic crime, though its effectiveness has at times been constrained by overlapping institutional responsibilities and systemic inefficiencies.

In the aftermath of the 2009 financial crisis, the Ministry of Finance institutionalized a whistleblower program that designated SDOE as the competent authority for complaint management. This initiative yielded a substantial increase in public revenue—from €1.7 billion in 2009 to €4.5 billion by 2012 (Chohan, UW, 2020).

To effectively combat organized financial crime and safeguard public fiscal interests, SDOE engages in extensive cooperation with other national and international institutions, including the Operations Coordination Center (SEK), the Hellenic Police, the Hellenic Coast Guard, the Independent Authority for Public Revenue (IAPR), the Anti-Money Laundering Authority (FIU), the European Public Prosecutor's Office (EPPO), Europol, OLAF, and the U.S. Drug Enforcement Administration (DEA).

### **Legal and Institutional Framework of the SDOE**

The institutional and operational mandate of the Financial and Economic Crime Unit (SDOE) is anchored in a structured legal framework that supports its role in the enforcement of financial and economic legislation in Greece. The principal legal instruments include:

- **Law 2343/1995:** Establishes the creation and initial organizational structure of the SDOE, laying the foundation for its function as a specialized financial crimes enforcement body.
- **Presidential Decree 85/2022:** Constitutes the most recent codification of the agency's regulatory and procedural framework.
- **Law 4622/2019:** Strengthens the strategic coordination of executive state functions, promoting more integrated public sector governance.
- **Law 4557/2018:** Provides the core legal framework for combating money laundering and financing of terrorism, aligning national provisions with EU directives.
- **Tax Procedure Code (Law 4174/2013):** Governs the administration and enforcement of tax obligations, ensuring procedural uniformity and legal certainty.

### **Law 3296/2004 (Articles 28 & 30)**

This legislation was pivotal in the restructuring and modernization of the SDOE's operational mandate.

- **Article 28** defines the agency's core mission: the detection and suppression of tax evasion, smuggling, corruption, money laundering, and other forms of organized economic crime.
- **Article 30** expands on the scope of auditors' powers, including authority for autonomous inspections, on-site investigations, and the seizure of both material and digital evidence, thereby enhancing audit effectiveness.

### **Law 3842/2010 (Article 80)**

This provision regulates the inter-agency cooperation framework, especially in regard to the exchange, management, and analysis of electronic tax-related data, facilitating cross-institutional coordination in audit activities.

### Presidential Decree 142/2017

This decree elaborates on the internal organizational architecture and functional protocols of the SDOE, detailing:

- The central and regional administrative structure;
- The delineation of responsibilities among internal departments and audit teams;
- The supervisory authority exercised by the Ministry of National Economy and Finance;
- Standardized procedures for audit operations and enforcement actions.

### 3. Audit Procedures

The audit processes implemented by the SDOE adhere to a rigorously defined and methodologically sound framework, which encompasses distinct sequential phases. These procedures are founded upon the principles of legality, transparency, and risk-oriented targeting, ensuring that audit activities are both effective and compliant with national and European legal standards.

The audit lifecycle involves the following stages: information collection, evaluation, issuance of the control order, on-site investigation, assessment of findings, management of evidentiary material, and submission of the final report. Each phase contributes to the overall integrity and efficacy of the investigative process.

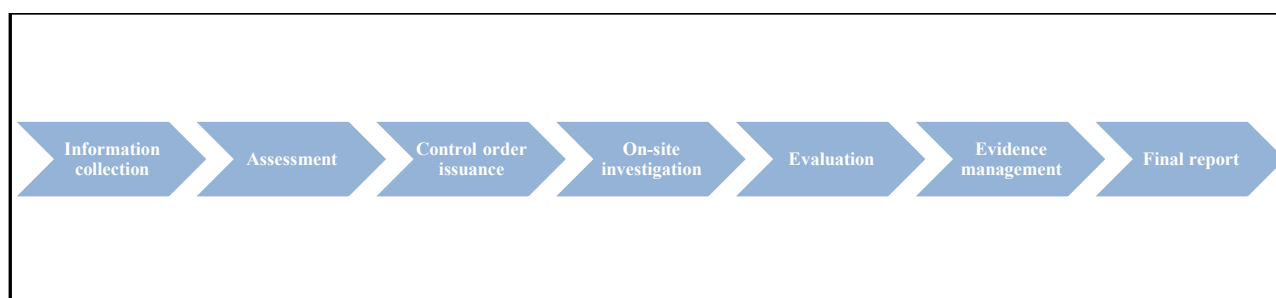


*Figure 2: Audits' procedures.*

Audits are based on principles of legality, transparency, and risk-based targeting.

#### Preliminary Stage: Information Gathering

The initiation of an audit is predicated upon the acquisition of pertinent 'information,' which may originate from diverse sources, including anonymous reports, formal complaints, or directives from prosecutorial authorities. Such information is documented in a standardized 'Information Sheet' that includes critical metadata such as the date and method of receipt, the origin of the information, a code denoting the suspected infraction, and a recommended priority level. This preliminary dossier is then enriched with auxiliary data drawn from institutional databases such as the General Secretariat for Information Systems (GSIS) and the European Anti-Fraud Office (OLAF), among others

#### Evaluation of Information

Following the preliminary collection of data, a supervisory body undertakes an evaluative process to determine the reliability and investigative value of the information. Information deemed credible and significant is escalated for the issuance of a formal audit order and the establishment of a corresponding case file.

## **Issuance of Audit Order**

The audit order is an official administrative act, signed by a designated supervisory officer. It specifies the parameters of the audit, including a unique order number and issuance date, the reference number of the originating information file, the identities of the appointed auditors, as well as the scope, duration, and geographic location of the inspection.

The origin of audit orders may be traced to complaints, systemic cross-checks, risk analysis assessments, or premeditated operational planning.

## **Execution of the Audit Order**

All audit orders are formally registered in the 'Daily Audit Planning Statement' and distributed to the relevant department heads. This ensures effective coordination and preparation prior to the execution of on-site procedures.

## **On-site Execution**

Field investigators are vested with a broad array of investigative powers, which include the authority to enter business premises, examine physical and electronic financial records, and seize documentation or digital evidence either temporarily or permanently, pursuant to Law 4712/2020. Moreover, they are empowered to perform arrests or issue summonses where legally warranted.

Investigators also make use of advanced technological platforms—such as Taxisnet and Elenxis—to trace financial transactions and freeze bank accounts, where applicable.

## **Pre-Investigation Powers (CCP, Article 31)**

Under Article 31 of the Code of Criminal Procedure, SDOE auditors are conferred the status of preliminary investigators. This designation authorizes them to file criminal cases, detain suspects, and refer investigative findings to the Prosecutor's Office when criminal conduct is substantiated.

## **Transmission of Findings**

Upon the conclusion of the audit, a comprehensive report is compiled and forwarded to the appropriate authorities. These include the Independent Authority for Public Revenue (IAPR)—specifically the Certification and Collection Centers (KEVEIS) and Customs— for administrative enforcement, the Prosecutor's Office for criminal proceedings, and other relevant bodies such as the Anti-Money Laundering Authority when applicable.

The audit and investigation flowchart of the D.G. S.D.O.E. presents a clear and structured approach to combating financial crime in Greece. It highlights procedural integrity, jurisdictional clarity, and effective cooperation among regulatory bodies. Such a framework supports transparency and aligns with European Union best practices.

## **Sources of Information and Initiation of Investigation**

The investigation process begins with inputs from various sources:

- Orders for preliminary examination by the Prosecutor's Office
- Public complaints
- Information bulletins from other authorities
- Other sources of intelligence

These are evaluated by a dedicated Evaluation and Classification Committee, which assesses the relevance, credibility, and urgency of each case.

## Jurisdictional Assessment

A key step is determining whether D.G. S.D.O.E. has the jurisdiction to handle the case. If so, the case is forwarded to the appropriate operational directorates for further action. If not, it is transferred to the competent authorities for appropriate processing.

## Investigative Procedures and Special Cases

When within jurisdiction, audits and preliminary investigative actions are undertaken. The gravity of the case is assessed - if deemed of exceptional severity, asset freezing measures may be applied to secure evidence and prevent asset concealment.

### Completion and Reporting:

Upon completion of investigations:

- If violations are confirmed, findings are sent to the Prosecutor, the Independent Authority for Public Revenue (IAPR), and the Anti-Money Laundering Authority (FIU).
- If no violations are found, the case is archived.
- Confirmed violations may lead to criminal charges, fines, and tax enforcement actions.

## Inter-institutional Collaboration

The flowchart underscores the collaborative efforts between multiple institutions:

- The Prosecutor's Office
- The Anti-Money Laundering Authority
- The Independent Authority for Public Revenue (IAPR)

These connections ensure comprehensive enforcement of financial crime laws.

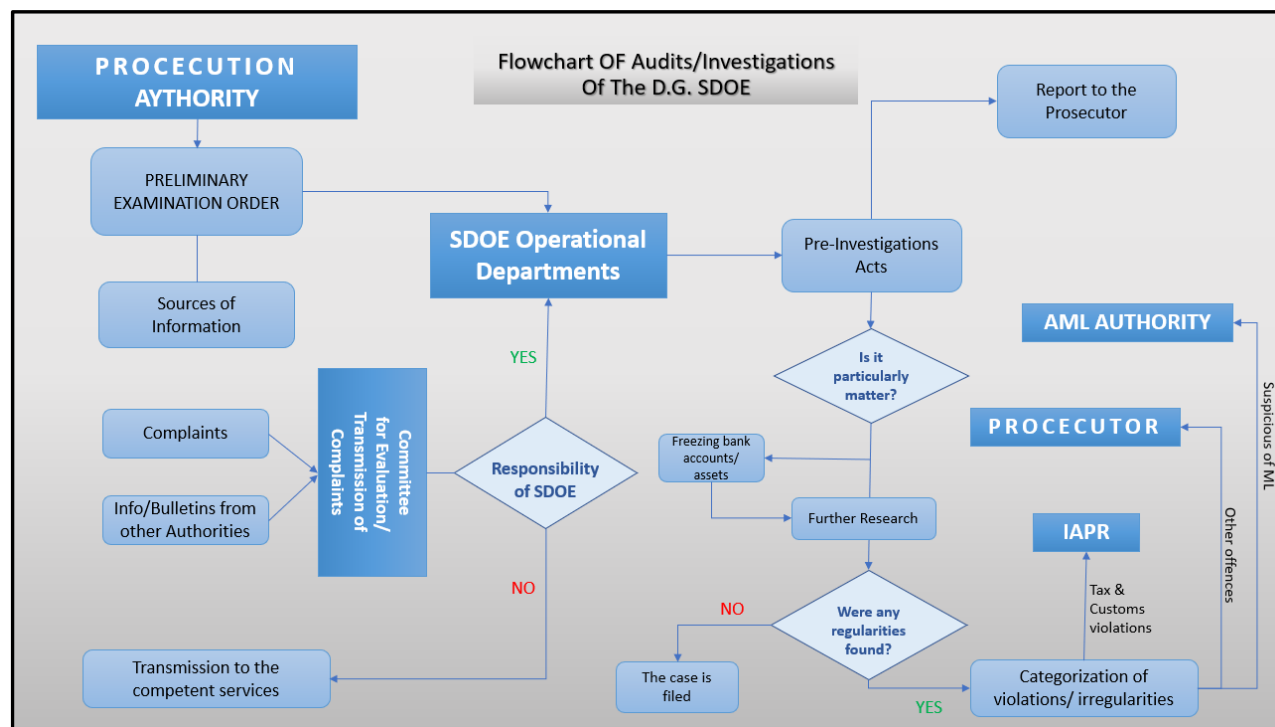


**Figure 3 : Flowchart of Investigations.**

Source: 2023 Annual Report – The Directorate General of SDOE - Ministry of National Economy and Finance.

The investigation process followed by officials includes several stages, which ensure compliance with the legislation and the effectiveness of the audits. The following is an analysis of the action flow process:

1. **Initial Order and Supervision:** Initiated via prosecutorial order. The audit begins with the order from the competent prosecutor, who is responsible for the supervision and guidance of the auditors. The prosecutor provides the instructions for the execution of the preliminary examination.
2. **Field Audits:** Conducted under prosecutorial direction. Investigators, under the guidance of the prosecutor, proceed to conduct audits. These audits include assessing compliance with legal requirements, recording findings, and collecting evidence.
3. **Documentation:** Full record-keeping of actions and evidence. Every action taken during the audit is recorded in detail. This documentation includes items such as reports, documents and other information related to the audit process.
4. **Report Writing:** Results and recommendations compiled. After completing the audits, auditors write a report that includes the results of the audits, their observations and suggestions for further actions.
5. **Report Submission:** Sent to Prosecutor for review. The report is sent to the prosecutor, who judges the course of the pre-trial proceedings and the next actions to be taken.
6. **Evaluation and Decision:** Prosecutor determines further legal action. The prosecutor evaluates the report and decides on the further course of the case, which may include the imposition of administrative fines or other legal actions.

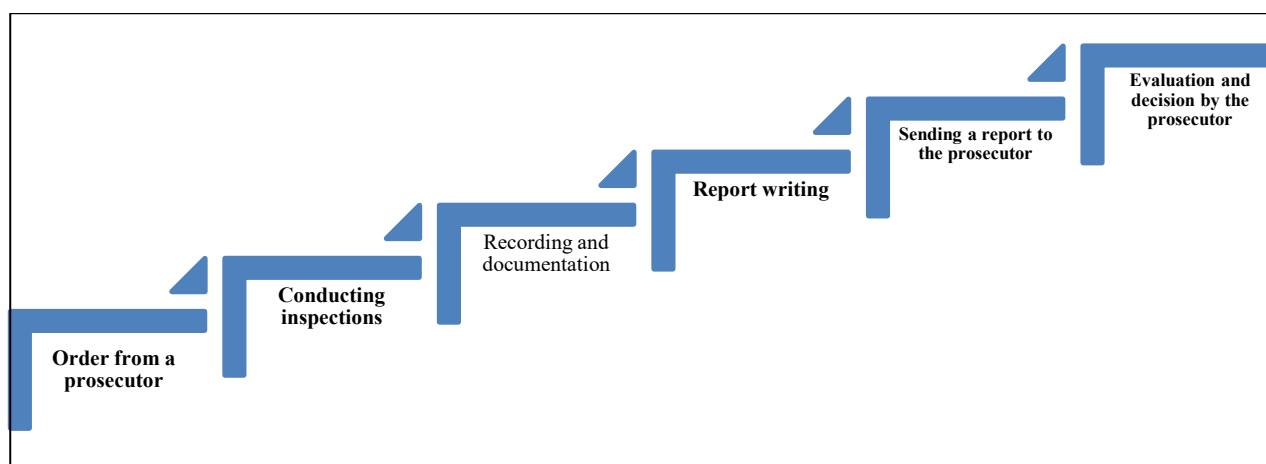


*Figure 4: Steps of the Audit Process*

Requests concerning cases of money laundering from criminal activities are assessed through a process that includes cooperation between the General Directorate of the Financial and Economic Crime Unit and the Anti-Money Laundering Agency. The operation of the SDOE has a central role in the national system for preventing and responding to such phenomena. When the audit reveals indications of the commission of predicate offences and money laundering, the Authority is informed so that immediate measures can be taken, such as the freezing of the perpetrators' assets. The employees of the SDOE act under the supervision of the prosecutor and draw up a report with the results of their actions, in order for the prosecutor to decide on the course of the case.

The Operational Directorates of the Financial & Economic Crime Unit (S.D.O.E.) conduct financial investigations to identify money laundering acts in parallel with investigations into the underlying

offense. Conducting a financial investigation is an essential tool for a modern and effective response to significant financial crimes. Through financial investigation, auditors-investigators identify strong evidence of criminal activities and they have the ability to map entire criminal networks through the financial flows between their members and take preventive measures such as recovering and freezing the proceeds of crime. This tool can be used in any case in which the commission of a underlying offense under article 4 of Law 4557/2018 is being investigated and indications of money laundering arise.

In order to maximize its potential benefits, it is important that financial investigation begins at an early stage of the investigations being conducted. Conducting parallel financial investigations contributes to the development of strong evidence for the criminal prosecution of criminals and the recovery of illegal proceeds. Considering all the aforementioned points regarding the improvement of the effectiveness of detecting and prosecuting money laundering phenomena, the following diagram illustrates the utilization of all of the above during the conduct of audits by the D.G. SDOE:

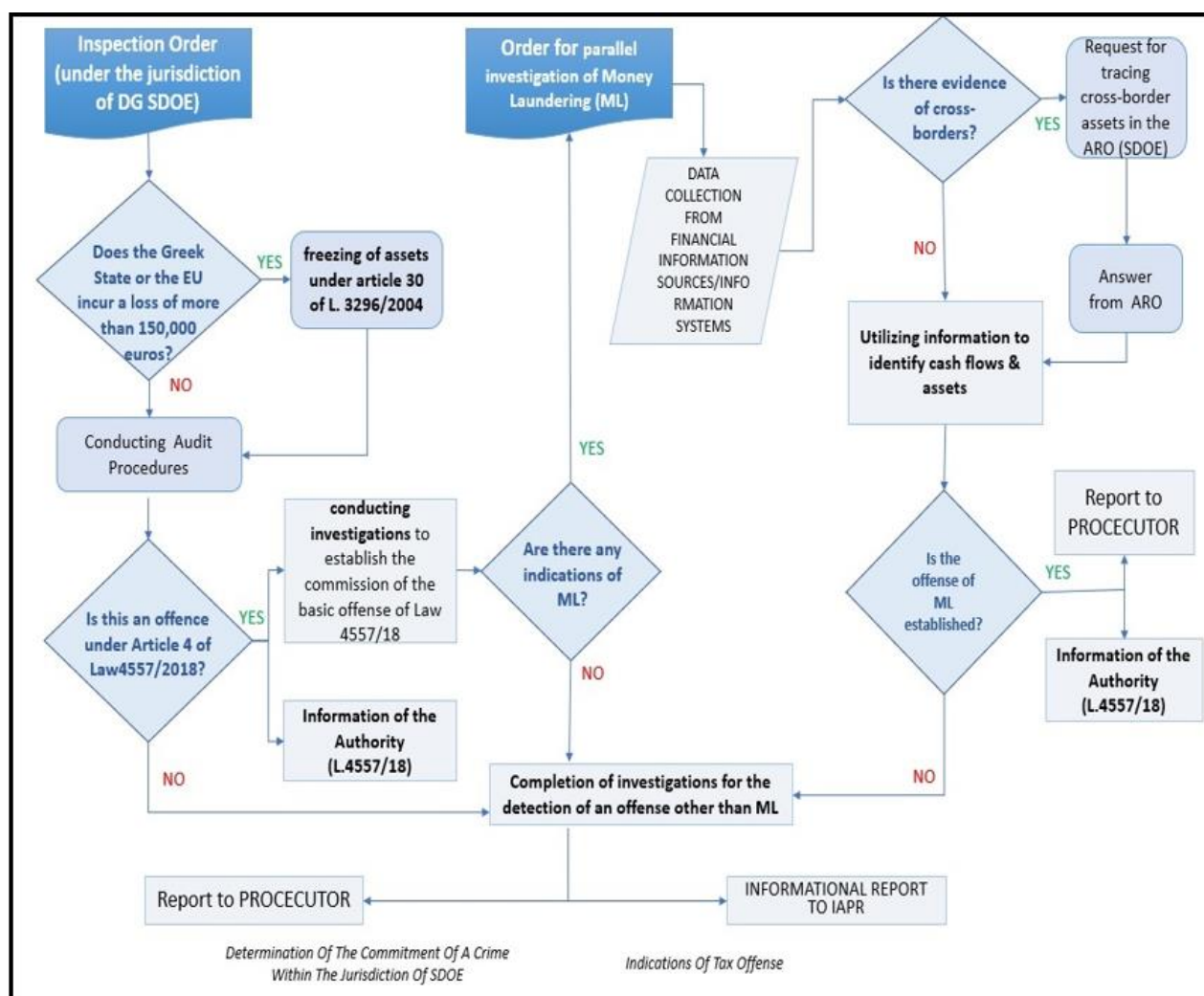


**Figure 5:** Investigation Procedure for Financial Crimes and Money Laundering.

Source: Annual Report – D.G. Financial & Economic Crime (SDOE) - Ministry of National Economy & Finance (2023).

Law enforcement services, such as the Operational Directorate of the Financial and Economic Crime Unit (SDOE), initiate the investigation process of suspected financial crimes such as tax evasion and money laundering (ML), always upon the issuance of an Order by its supervisor. Subsequently, the financial impact on the budgets of the Hellenic Republic or the European Union is assessed. If the

damage caused is equal to or greater than €150,000, the auditors of SDOE, based on Article 30 of Law 3296/2004, proceed with the immediate freezing of the assets of the involved parties. If the estimated damage is below the €150,000 threshold, the auditors proceed with further investigative actions.

In the second phase, the financial offense committed is evaluated on a legal basis. If the offense falls under Article 4 of Law 4557/2018, the auditors proceed with investigations to confirm the commission of the underlying offense, and an information report is submitted to the Financial Intelligence Unit (FIU): Authority for Combating Money Laundering from Criminal Activities in Greece. At this point, if there are indications that may lead to the offense of money laundering, an Order is issued for a parallel investigation for money laundering, and the team of assigned investigators proceeds with collecting data from financial information sources and databases.

In the event of cross-border financial transactions, a request is submitted to the Asset Recovery Office (ARO) to trace transnational assets. Following ARO's response, an in-depth analysis of cash flows and other assets is conducted regardless of whether international transactions occurred.

If the offense of money laundering from criminal activities is substantiated, a report is submitted to the FIU (Law 4557/18) and a referral is made to the Prosecutor.

In contrast, if the offense of money laundering is not substantiated—as in the second phase, or in cases where the offense does not fall under Art.4 of Law 4557/2018—the auditors conclude their investigation by preparing a final report identifying offenses other than money laundering. The case is then forwarded either to the Prosecutor if the offense falls within SDOE's jurisdiction, or to the Independent Authority for Public Revenue (IAPR) if tax-related offenses are indicated.

This process ensures a methodical and legally sound approach to combating economic crime and upholding financial transparency within Greece and across EU borders.

#### **4. Collaborations and Interoperability**

The efficacy of the Financial and Economic Crime Unit (SDOE) in detecting and combating economic offenses is significantly augmented through its institutional collaborations and technological interoperability with other domestic and international entities. In alignment with the principles of transparency and administrative efficiency enshrined in Law 4440/2016, the SDOE has cultivated operational synergies with a broad range of partners, including the Independent Authority for Public Revenue (IAPR), the Directorate for the Fight against Organized Crime (DAOE), the European Anti-Fraud Office (OLAF), and the European Union Agency for Law Enforcement Cooperation (EUROPOL).

The seamless integration of interoperable information systems such as NEO TAXIS, ICISnet, and ELENXIS plays a pivotal role in enhancing the unit's capacity to conduct data-driven audits, execute cross-referenced investigations, and minimize delays in inter-agency communication. These platforms enable real-time data exchange, analytical intelligence, and coordinated enforcement actions—fundamental prerequisites for an effective audit and investigative apparatus within the contemporary financial crime landscape.

Through these partnerships and system integrations, the SDOE ensures a multidimensional response to financial misconduct that transcends institutional silos, promoting a unified front in safeguarding fiscal integrity and public trust.

## 5. Use of Social Media: Legality, Audit Phases, and Anti-Crime Strategy

### 5.1 Usefulness of Social Media in Audits

In the context of contemporary financial audits and investigations, social media platforms have emerged as a valuable auxiliary tool for detecting discrepancies between declared income and actual lifestyle, as well as for uncovering indicators of illicit economic activity. The SDOE leverages publicly available digital footprints to cross-reference information derived from traditional audit channels, thereby enriching the evidentiary base and enhancing the precision of its assessments. Social media content can reveal patterns of consumption, undeclared professional activities, and potential affiliations with suspect networks.

### 5.2 Legal Basis for Use of Social Media

#### 5.2.1 The GDPR and national legislation

Thanks to new technologies, tax administrations have been collecting and processing a very high number of taxpayers' data from different sources. These sources include, among others, social media. Data can be used in tax collection, monitoring and for supporting auditing decisions. Indeed, by receiving and processing more data, tax administrations will be able to reduce information asymmetries which represent a threat to equal and complete tax collection (Scarcella, 2019). The use of social media in the processing of taxpayers' data, including personal data, brings uncertainty in relation to the breaching of privacy rights and personal data protection rights.

On the one hand, it must be noted that the privacy right refers to the individuals' right to define their private space by choosing if, when, and to what extent they interact with and reveal themselves to others (Wu, 2014). In this sense, information published on social media loses its private character, especially when the account holder has his profile publicly accessible or when many friends or followers log in to that profile. Therefore, the invocation of the protection of privacy cannot apply in the case of information published on social media. On the other hand, personal information itself constitutes personal data and does not lose its status simply because it has been made public. In other words, personal data is not only private or confidential personal information, but any information that can identify a person (Kovalenko, 2022). In this sense, every user's profile with personal data is protected against illegal access, dissemination and use of information for other goals different from the defined (Romansky, 2014). Thus, the processing of personal information posted on social media by a public or private entity, which is a third party in relation to the data subject, falls within the scope of the European Regulation 2016/679 "*on the protection of natural persons against the processing of personal data*" (GDPR). This legislation imposes strict provisions regarding the collection and any other act of processing personal data and significantly strengthens the rights of natural persons.

In the second place, it is necessary to examine whether the operation by which the tax authorities of a Member State seek to collect from social media personal data concerning certain taxpayers may be regarded as excluded from the scope of Regulation 2016/679 under Article 2(2) thereof. This article provides that the GDPR does not apply to the processing of personal data by competent authorities for the purposes of the prevention, investigation, detection or prosecution of criminal offences or the execution of criminal penalties. Directive 2016/680, which was adopted on the same day as Regulation 2016/679, defines 'competent authority' in Article 3(7) (Salami, 2017). This concept must be understood in relation to the the fields of judicial cooperation in criminal matters and police cooperation, in view of the arrangements which may prove necessary, in that regard, because of the specific nature of those fields (Latvijas Republikas Saeima, paragraph 70). In the light of all the foregoing considerations, the collection by the tax authorities of a Member State from social media of information involving a significant amount of personal data is subject to the requirements of that

regulation, particularly those set out in Articles 5(1) and 6 thereof (Valsts ieņēmumu dienests, paragraph 42).

According to this regulation, the lawfulness of the processing of personal data presupposes the combined existence of the principles and legal bases set in articles 5 and 6. Personal data must be processed lawfully, fairly and in a transparent manner in relation to the data subject (Latvijas Republikas Saeima, paragraph 99). Processing by public Authorities is lawful only if and to the extent that processing is necessary -among others- for compliance with a legal obligation to which the controller is subject (6c) or the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller (6e) (Digi, paragraph 49). These justifications provided for in those latter provisions, must be interpreted restrictively (Valsts ieņēmumu dienests, paragraph 73).

Regarding the processing of personal data for compliance with a legal obligation, for the performance of a task carried out in the public interest or in the exercise of official authority vested in the controller, Member States are allowed to maintain or introduce **national provisions** to further specify the application of the rules of this Regulation. To that extent, GDPR does not exclude Member State law that sets out the circumstances for specific processing situations, including determining more precisely the conditions under which the processing of personal data is lawful (Scarcella, 2019). For example, sharing of personal data is encouraged in many countries for economical and efficiency purposes. [recital 10].

Such case is the article 22(1) of the Greek law 4624/2019. This article permits the processing of personal data by public authorities for a purpose other than that for which they were collected, when the processing is: a) Necessary to check the information provided by the data subject, because there are reasonable indications that this information is incorrect; b) Necessary to prevent risks to national security, national defense or public safety or to secure tax and customs revenue; c) Necessary for the prosecution of criminal offences; d) Necessary to prevent serious damage to the rights of another person; e) necessary for the production of official statistics.

The performance of a task carried out in the public interest or in the exercise of official authority covers situations where the controller itself has an official authority or a public interest task (but not necessarily also a legal obligation to process data) and the processing is necessary for exercising that authority or performing that task. GDPR refers to the example of a tax authority, which may collect and process an individual's tax return to establish and verify the amount of tax to be paid.

In addition to the legal bases, lawful processing requires compliance with the principles of Article 5. Personal data must be collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those ("**purpose limitation**") in accordance with the principle of proportionality, which is now a key principle for the lawful limitation of any right. Data must be adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed ("**data minimization**") (Asociația de Proprietari bloc M5A-ScaraA, paragraph 48). These principles not only provide a reasonable balance for the interests of data controllers and data subjects, but they also limit and define the exercise of state power to the extent strictly necessary in accordance with the fundamental principle of the rule of law (Zalnieriute et al., 2019).

### 5.2.2 Other Legal Provisions

The legal foundation for the use of social media in audit and investigative functions is delineated in several legislative provisions:

- Article 30 of Law 3296/2004 authorizes the collection of data from any lawful source.
- Article 80 of Law 3842/2010 permits the utilization of electronic means for audit verification.
- Article 31 of the Code of Criminal Procedure legitimizes all lawful investigative techniques.

- Law 4624/2019 ensures that the use of publicly available personal data complies with the General Data Protection Regulation (GDPR).

These provisions collectively enable the legal exploitation of digital evidence derived from social platforms, provided it is acquired and processed in a manner consistent with the principles of legality, necessity, and proportionality.

### **5.2.3 Limitations**

Despite the operational benefits, the utilization of social media is subject to strict legal constraints. Only content that is publicly accessible—such as images, posts, videos, or geolocation data—may be employed for audit purposes. Unauthorized access methods, including digital intrusion or password circumvention, are explicitly prohibited. Furthermore, any insights derived from social media must be corroborated through independent evidence or cross-referenced with official databases to maintain their probative value.

## **5.3 Audit Stages Involving Social Media**

During the preliminary phase of an audit, social media analysis may be employed to identify indications of undeclared income or lifestyle incongruent with reported earnings, verify allegations contained in complaints, or detect unauthorized commercial activity.

As the audit progresses, digital evidence extracted from social platforms can support on-site investigations by providing contextual insights, pinpointing collaborators, or identifying physical locations of relevance.

## **5.4 Criminal Investigation**

In cases where criminal proceedings are pursued, social media may assist in establishing intent, identifying the material benefit derived from unlawful acts, or substantiating money laundering activities. This digital evidence is compiled and submitted to the Prosecutor for inclusion in the criminal case file.

## **6. Policy Proposals to Enhance Anti-Crime Action**

To further fortify the institutional capacity of the SDOE in its efforts to combat complex financial crime, a series of strategic policy proposals have been identified. These recommendations aim to bridge existing operational gaps, enhance inter-agency cooperation, and align the unit's investigative tools with contemporary technological advancements. Emphasis is placed on the development of digital capabilities, legal codification of digital evidence use, and the cultivation of a proactive compliance culture within the broader fiscal ecosystem.

### **Digital Data Use Directive**

The issuance of an official circular clarifying the scope and limitations of digital data collection—particularly from social media and online platforms—would ensure legal certainty and prevent arbitrary enforcement. This directive would codify the acceptable parameters for the use of such data in audit and prosecutorial contexts.

### **Specialized Digital Surveillance Training**

Auditors should receive advanced training in digital forensics and online surveillance methods. Such capacity building would equip personnel with the technical acumen required to extract, interpret, and lawfully utilize digital evidence, thereby enhancing the effectiveness of modern audit operations.

### **National Data Analytics Platform**

The establishment of a unified digital platform capable of integrating data from tax records, commercial registries, social media, and financial institutions would facilitate holistic risk assessments and real-time cross-referencing during audits. This platform would serve as a cornerstone for a data-driven governance framework.

### **Legal Recognition of Digital Public Data**

Legislative amendments recognizing publicly accessible digital content as admissible audit evidence—subject to strict safeguards—would formalize its use and ensure consistency in judicial interpretations. These amendments would also reinforce the balance between investigative utility and privacy rights.

### **Enhanced Institutional Interoperability**

Real-time data sharing mechanisms among key institutions such as the IAPR, SDOE, DAOE, OLAF, and prosecutorial authorities would eliminate redundancies, streamline case management, and enable synchronized enforcement actions.

### **Promoting Compliance Culture**

The cultivation of a compliance-oriented culture requires continuous public engagement. Targeted awareness campaigns, educational programs, and incentive structures for whistleblowers could significantly increase citizen participation in the fight against financial crime and reinforce voluntary adherence to tax and regulatory obligations.

## **7. Conclusions**

The Financial and Economic Crime Unit (SDOE) plays a critical role in Greece's institutional response to economic and fiscal misconduct. Its statutory mandate, supported by a multi-tiered legal framework, enables the agency to investigate complex financial crimes with both authority and flexibility. However, the evolving nature of financial criminality—particularly in the context of digital platforms and global networks—necessitates a corresponding evolution in operational practices and institutional capabilities.

The integration of digital evidence, including data derived from social media, represents a significant advancement in audit methodology. When implemented in accordance with the principles of legality, proportionality, and transparency, such tools can greatly enhance the precision, efficiency, and evidentiary value of financial investigations. Nonetheless, the effective deployment of these technologies requires not only legal certainty, but also robust inter-agency interoperability and specialized auditor training in digital forensics and cyber intelligence.

To this end, the modernization of the SDOE must proceed along three strategic axes: (i) the institutionalization of clear legal norms governing digital surveillance and data analytics; (ii) the continuous development of technical and human capital; and (iii) the enhancement of interconnectivity between auditing bodies and emerging digital infrastructures. Only through such a multidimensional reform strategy can the state adequately respond to the challenges of financial crime in an increasingly digitized and complex economic landscape.

## Abbreviations

DAOE Directorate for the Fight against Organized Crime  
DEA Drug Enforcement Administration  
D.G. Directorate General  
ELENXIS Integrated Audit Information System  
EPPO European Public Prosecutor's Office  
EUROPOL European Union Agency for Law Enforcement Cooperation  
FATF Financial Action Task Force  
FIU Financial Intelligence Unit (Anti-Money Laundering Authority in Greece)  
GDPR General Data Protection Regulation  
GSIS General Secretariat for IT Systems  
IAPR Independent Authority for Public Revenues (AADE)  
ICISnet Customs Integrated System  
INTERPOL International Criminal Police Organization  
KEVEIS Certification & Collection Centers  
NEO TAXIS Integrated Tax Information System  
OLAF European Anti-Fraud Office  
SDOE Financial and Economic Crime Unit  
SEK Operations Coordination Center  
SOCMINT Social Media Intelligence

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# The economic and social profiles of investors in renewable energy sources

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## Abstract

The imperative for a global transition to clean energy is driven by the urgent need to mitigate climate change, ensure long-term energy security, and stimulate sustainable economic growth. Renewable energy sources (RES), encompassing solar, wind, hydroelectric, and geothermal technologies, have emerged as critical instruments in this transformation. These technologies not only mitigate adverse environmental impacts but have also achieved economic competitiveness, often surpassing fossil-based alternatives in cost-efficiency, job creation, and long-term financial viability. According to the International Renewable Energy Agency (IRENA, 2023), renewables generate nearly three times more employment per dollar invested than conventional energy sources. This study seeks to explore the economic and social profiles of investors in RES by integrating financial evaluation metrics—namely Net Present Value (NPV), Internal Rate of Return (IRR), and Profitability Index (PI)—with detailed socio-demographic analysis. Through this interdisciplinary framework, we aim to identify the factors that drive or inhibit investment behaviors, providing insights that can inform targeted policy instruments, financial innovation, and community engagement strategies essential to facilitating a just and inclusive energy transition.

**Keywords:** *Renewable energy, sustainable investment, Net Present Value (NPV), Internal Rate of Return (IRR), Profitability Index (PI), socioeconomic analysis.*

## 1. Introduction

The global shift toward sustainable energy systems is increasingly recognized as a necessary response to the escalating climate crisis and the socio-economic risks associated with continued reliance on fossil fuels (Adewumi et al. (2024)). Renewable energy sources (RES) are at the heart of this transformation, offering environmentally sustainable and economically viable alternatives for energy generation (Jaiswal et al., 2022). Over the past decade, RES have experienced accelerated deployment across multiple regions, driven by a confluence of factors such as declining capital costs, advancements in technology, and supportive policy frameworks (IEA (2022); Lazard (2023)). This trend has led to the growing recognition of RES as essential for achieving both decarbonization goals and sustainable economic development.

However, while the macroeconomic advantages of renewable energy are well-documented, the micro-level dynamics of investor behavior remain insufficiently explored. Understanding who invests in renewable energy, under what conditions, and for what motivations is vital for designing inclusive financial mechanisms and policy tools that encourage broader participation in the energy transition.

Particularly underexplored are the social characteristics and motivations of investors in small- and medium-scale RES projects, such as residential solar installations or local energy cooperatives (Andrews and Johnson, 2016).

This paper aims to bridge that gap by examining the interplay between financial viability and investor socio-demographics. Specifically, we employ financial evaluation tools NPV, IRR, and PI to assess the economic rationality behind RES investments. These tools are applied in conjunction with an analysis of demographic and attitudinal variables such as income level, education, geographic context, and environmental awareness. By adopting this dual lens, we aim to provide a comprehensive perspective on the decision-making processes underlying investments in RES. Ultimately, the findings contribute to a more holistic understanding of the investment landscape, with implications for policy-making, financial innovation, and outreach strategies designed to promote equitable participation in renewable energy markets.

## 2. Related Work

A growing body of literature addresses both the economic feasibility of renewable energy projects and the behavioral dimensions of energy-related decision-making (Huckebrink and Bertsch, 2021). On the financial front, numerous studies by institutions such as the International Energy Agency (IEA (2022)) and (REN21, 2023) underscore the increasingly competitive nature of RES, particularly in terms of long-term cost savings and return on investment. Financial tools such as NPV, IRR, and PI have been widely employed to assess project feasibility, factoring in capital expenditure, operational costs, discount rates, and policy incentives such as subsidies or feed-in tariffs (Brealey, Myers and Allen, 2014).

Simultaneously, research in behavioral economics and energy sociology has shed light on the importance of non-financial drivers of RES investment. For example, (Sachs et al., 2019) emphasize that factors such as trust in energy providers, perceived risk, and environmental values significantly shape investment choices. Likewise, (Bauwens, Gotchev and Holstenkamp, 2016) highlight the importance of community engagement and social capital in facilitating the success of cooperative energy models. Li (2023) argue that understanding energy transitions requires not only financial modeling but also attention to cultural, institutional, and behavioral contexts.

Despite the richness of this literature, integrated analyses that combine rigorous financial modeling with detailed investor profiling are relatively rare. Notable exceptions include (Rode and Weber, 2016), who found that income and peer effects strongly influence household-level adoption of rooftop solar in Germany. However, comprehensive, cross-contextual studies that systematically account for both economic and social determinants of RES investment remain limited. This study seeks to contribute to this gap by offering an integrated framework capable of informing both academic discourse and policy development.

## 3. Methodology

To achieve a comprehensive understanding of the economic and social dimensions of RES investment, this study adopts a mixed-methods approach that integrates financial modeling, socio-demographic analysis, and comparative case studies. From a financial standpoint, the analysis employs three widely used investment evaluation metrics:

- (a) Net Present Value (NPV), which estimates the net monetary benefit of a project over time by discounting future cash flows;

$$NPV = \sum_{t=0}^n \frac{Rt}{(1+i)^t}$$

- (b) Internal Rate of Return (IRR), which indicates the discount rate at which the project's NPV becomes zero and thus provides a benchmark for investment attractiveness; and

$$IRR = \frac{(Future\ Value)^{\frac{1}{period}}}{Present\ Value} - 1$$

- (c) Profitability Index (PI), which represents the ratio of discounted cash inflows to the initial capital investment.

$$PI = 1 + \frac{NPV}{Initial\ Investment}$$

These tools allow for a systematic comparison of different RES technologies and project types, such as photovoltaic solar, onshore wind, and micro-hydropower systems, under varied assumptions related to market prices, subsidy regimes, and operational efficiencies.

In parallel, the study conducts a socio-demographic analysis of RES investors using secondary data from international and national statistical sources including Eurostat, the World Bank, and IRENA. Key variables include income level, educational attainment, urban or rural residency, environmental attitudes, and investment type (individual, cooperative, or institutional). These data are used to construct typologies of investor behavior and to identify patterns across different socio-economic segments.

To contextualize and validate the quantitative findings, the study includes a series of case studies from countries with differing levels of RES market development and regulatory environments. Specifically, we examine Germany, with its mature and decentralized renewable energy sector; Greece, where regulatory reforms are spurring new prosumer models; Brazil, characterized by socio-economic inequality and a predominantly hydro-based energy mix; and Kenya, notable for its innovations in off-grid renewable energy solutions. These cases serve to illustrate how local contexts shape the interaction between financial and social factors in RES investment.

Expected outcomes of the methodology include the identification of both enabling and inhibiting factors in renewable energy investment. We anticipate that favorable financial metrics—particularly when enhanced by supportive policy instruments—will correlate strongly with high investment levels. However, we also expect to find that socio-economic attributes such as income, education, and environmental engagement significantly mediate the decision to invest, sometimes even overriding purely economic considerations. In this way, the methodology not only evaluates project profitability but also uncovers the broader socio-economic landscape that underpins investment behavior.

### 3. Conclusions

This study underscores the need for an integrated approach to understanding investment behavior in the renewable energy sector. While traditional financial models such as NPV, IRR, and PI provide valuable insights into the profitability of RES projects, they are insufficient to capture the full range

of motivations and constraints that shape investment decisions. Socio-demographic factors, income level, education, geographic location, and environmental consciousness, play a crucial role in determining who invests, in what kind of projects, and under which conditions.

Our findings suggest that policy efforts aimed at expanding renewable energy deployment must go beyond economic incentives and address the socio-structural barriers that limit participation. Measures such as inclusive financing schemes, education campaigns, and support for community-based energy models may be critical in democratizing access to clean energy investments. Future research should aim to refine the empirical models used for investor profiling, incorporate longitudinal data, and explore the dynamic interplay between policy, behavior, and market evolution. In doing so, we can support more effective and equitable pathways to a sustainable energy future.

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# Incident reporting systems in logistics and supply chain management

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## Abstract

Incident reporting systems (IRS) are increasingly recognized as indispensable instruments for risk governance and continuous improvement in logistics and supply-chain management. This study defines IRS within the supply-chain context, classifies the principal IRS archetypes used in enterprise systems, accounting, logistics operations, and strategic management, describes the socio-technical design process underpinning effective IRS implementation, and evaluates the added value of IRS through empirical evidence. The literature analysis confirms that a well-designed IRS operates as a cyclical learning mechanism comprising intuitive front-end reporting, systematic validation and classification, rigorous root-cause investigation, tracked corrective actions, and transparent organizational feedback. Four salient IRS categories are identified—enterprise-wide, accounting/financial, operational logistics, and strategic risk registers—each fulfilling distinct yet complementary functions across the supply-chain hierarchy. Critical success factors include top-management commitment, user-centred system design, and continuous feedback to reporters; conversely, under-reporting and data overload remain persistent challenges. The paper concludes that incident reporting is a cornerstone of modern supply-chain resilience and offers a research agenda centered on predictive analytics, cross-industry data sharing, and cultural incentives for robust reporting practices.

**Keywords:** *Incident reporting systems, supply-chain management, critical factors.*

## 1. Introduction

Incident reporting systems (IRS) are vital tools in modern logistics and supply chain management (SCM) for capturing and learning from any event that disrupts operations or poses risk. In high-velocity supply chains, accidents, delays, quality defects, and security breaches can occur despite preventive measures. An IRS provides a formal mechanism to document such **incidents**, including accidents and near-misses, and analyze their causes, enabling organizations to improve safety, compliance, and resilience (McLean et al., 2022) (Petschnig and Haslinger-Baumann, 2017). In essence, “an Incident Reporting System (IRS) is a way to report, document, investigate, and use the learning from incidents within the organization” (Nektar.io, n.d.). By systematically recording incidents and extracting lessons, companies can pinpoint weaknesses in processes and implement corrective actions before minor issues escalate into major failures. This paper defines IRS in the logistics/SCM context, categorizes key types of IRS (in enterprise systems, accounting, logistics

operations, and management), outlines how to design an effective IRS, and discusses the added value of IRS with empirical evidence from real-world cases, focusing on experiences in the EU, UK, USA, and Australia. The discussion uses formal academic language and draws exclusively on peer-reviewed literature from the last ten years.

## 2. Defining Incident Reporting Systems in SCM

Within logistics and SCM, an **Incident Reporting System** refers to a structured process (often supported by software) for capturing information about any unintended event that *deviates from normal operations*, analyzing its root causes, and disseminating lessons learned. IRS is considered a fundamental component of organizational safety and risk management. They typically encompass procedures and tools for front-line employees to report incidents (e.g., a warehouse injury, a shipment damage, an IT outage), for managers to review and investigate these reports, and for the organization to learn and improve. The ultimate goal is **organizational learning**: transforming incident data into preventive actions and safer processes. Studies emphasize that an effective IRS not only documents adverse events but also fosters a “*reporting culture*” where staff feel encouraged to report problems without fear. This aligns with the broader shift toward proactive risk management in supply chains, where learning from small-scale failures or “near misses” can prevent larger disasters. It has been noted that a well-implemented reporting system allows identification of hazards, and critical situations such as ‘near misses’ (Jones, Kirchsteiger and Bjerke, 1999), providing opportunities to intervene before these issues lead to serious incidents. In summary, an IRS in SCM is a *socio-technical system* comprising reporting protocols, analytical methods, and a supportive safety culture – all aimed at continuous improvement of logistic operations through incident feedback.

## 3. Types of Incident Reporting Systems in Enterprise, Accounting, Logistics, and Management

Incident reporting systems can be categorized by their scope and the domain of incidents they address. In logistics and SCM settings, organizations often deploy multiple, overlapping IRS tailored to different needs – from enterprise-wide platforms to department-specific tools. **Table 1** summarizes key types of IRS and their typical focus areas in SCM.

Table 1: Categories of Incident Reporting Systems in Logistics/SCM

| Category of IRS                         | Typical Context in SCM                                                                 | Purpose and Focus                                                                                                                                                                                                                                                                                        |
|-----------------------------------------|----------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Enterprise-Wide Incident Systems</i> | Integrated into Enterprise Resource Planning (ERP) or EHS platforms across the company | Company-wide reporting of safety, security, or quality incidents across departments. Links incident data with business functions (e.g., HR, maintenance) for holistic risk management. Enables real-time incident notification and coordinated response enterprise-wide (AlMarri et al. (2025).          |
| <i>Accounting and Financial IRS</i>     | Finance, auditing, and compliance programs                                             | Reporting of financial irregularities, fraud, or compliance violations (often via confidential whistleblowing hotlines). Logs incidents like accounting errors, theft, or bribery to ensure regulatory compliance and ethical standards. Interfaces with corporate governance and legal risk management. |
| <i>Logistics and Operational IRS</i>    | Supply chain operations (warehouses, transport fleets, distribution centers)           | Captures accidents, injuries, equipment failures, near-misses, and shipment incidents in daily operations. Focuses on occupational health and safety (OHS) and operational disruptions. Enables root cause analysis and prevention of recurring issues (e.g., forklift accidents, inventory damage).     |

|                                     |                                                                     |                                                                                                                                                                                                                                                                                   |
|-------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Management and Strategic IRS</i> | Upper management, risk management, and business continuity planning | High-level incident registers and risk management systems for executives to track major incidents and strategic risks (e.g., factory fires, logistics partner failures). Supports decision-makers in assessing trends and lessons for strategic planning and resilience building. |
|-------------------------------------|---------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Enterprise-wide IRS:** Large logistics companies often embed incident reporting into their **enterprise systems**. For example, many ERP suites now include an EHS (Environment, Health & Safety) or incident management module<sup>5</sup>. Furthermore, web-based ERP incident systems allow real-time reporting and notification, which “*enhance operational efficiency by enabling rapid response and emergency team mobilization*”<sup>5</sup>. Such enterprise-wide IRS facilitate cross-functional visibility: a single platform can capture incidents from a warehouse, a finance office, or an IT system outage. Integration with enterprise data (e.g. linking an incident to a work order or personnel record) means investigations are informed by rich context. Moreover, enterprise IRS often include analytics dashboards that track incident frequency, categorize root causes, and monitor closure of corrective actions. This aligns incident management with overall performance management and compliance requirements. For instance, an ERP-linked IRS can automatically notify the safety manager and relevant department head when an incident report is filed, trigger an investigation workflow, and later feed the findings into management review meetings. By breaking down information silos, enterprise incident systems ensure that lessons learned in one part of the supply chain (say, a recurring equipment failure in a distribution center) are visible to all relevant stakeholders and can prompt network-wide improvements.

**Accounting and Financial IRS:** Within the scope of corporate governance, organizations also maintain incident reporting mechanisms for financial and compliance-related incidents. These are a specialized subset of IRS focused on **accounting irregularities** and ethical misconduct. Many large firms (especially in the EU, UK, and US) have confidential **whistleblower reporting systems** to allow employees (or even suppliers) to report incidents such as fraud, theft, bribery, or violations of financial controls. While not always termed “incident reporting systems” in a narrow sense, these hotlines and compliance reporting tools fulfill a similar role: they capture the details of an incident (e.g. an observed fraud or a violation of procurement policy), route it to investigators (internal audit or compliance officers), and track the resolution (investigation outcome, disciplinary action, and control improvements). Such systems have gained prominence due to regulations (for example, the EU Whistleblowing Directive 2019/1937 and the Sarbanes-Oxley Act in the US) that mandate formal channels for reporting wrongdoing. From an SCM perspective, financial incidents can directly impact supply chain continuity (consider the fallout from a procurement fraud scandal or cost-reporting errors). Therefore, incident reporting in accounting provides oversight that indirectly supports supply chain reliability by ensuring financial stability and compliance. While academic literature on accounting-specific IRS is sparse, the value is reflected in industry surveys: organizations with active internal reporting channels detect issues earlier and reduce monetary losses<sup>2</sup>. In practice, accounting IRS integrate with case management systems where each report is logged as a “case” and managed through investigation stages, analogous to how safety incidents are managed in operational IRS.

**Logistics and Operational IRS:** These systems are at the heart of incident management in supply chain operations. They include **safety incident reporting systems** on the warehouse floor, **transportation incident logs**, and other operational reporting tools tailored to logistics activities. A typical logistics IRS might be a digital form or application that drivers use to report a road accident or that warehouse staff use to report an injury or a near-miss (such as a narrowly avoided collision of equipment). Capturing near-misses is especially important, as they often signify underlying hazards. As (Luthra and Mangla, 2018) emphasize in a supply chain risk context, minor daily disruptions can accumulate into significant performance issues if not addressed – hence recording these “small” incidents is crucial for continuous improvement (though Luthra & Mangla’s focus is on risk factors

broadly, the principle applies to incident logging). In practice, operational IRS tend to be **decentralized** (implemented at each site or business unit) but with aggregate data rolled up to the corporate level. For example, a global logistics firm might have each warehouse report incidents locally into a shared system; regional safety managers review local reports weekly, and corporate safety leaders analyze enterprise-wide trends monthly. Common types of incidents logged include workplace injuries, property damage, *vehicle accidents*, cargo spillage or contamination, delays due to vehicle breakdowns, and safety rule violations. Each incident record typically captures what, when, where, who, and a description of the event, often accompanied by classifications (severity, type of incident) and immediate actions taken. Over time, the data allows identification of systemic problems. Empirical studies underscore the benefit: **learning from frequent operational incidents improves safety and reliability**. One study in the maritime safety domain (Ghonaim, 2020) found that encouraging crews to report near-misses led to better awareness of hazards and a reduction in major accidents (as latent issues were addressed). More broadly, incident data in logistics serves as a basis for **risk analysis** techniques. For instance, if many truck drivers report brake issues as near-miss incidents, the fleet manager can initiate a preventive maintenance campaign. Without an IRS, such patterns might go unnoticed until a serious accident occurs. Thus, the added granularity and timeliness of incident information are invaluable for operational risk control.

**Management and Strategic IRS:** At the management level, companies aggregate incident information to inform strategic decision-making and enterprise risk management. These can take the form of **incident dashboards** for executives or inclusion of incident metrics in key performance indicators. Often, this is not a separate software system but rather a practice of *elevating critical incidents to the board level* and maintaining a log of high-impact incidents. For example, a supply chain director might keep a “risk register” that records significant supply chain disruptions (factory fires, port strikes, natural disasters affecting suppliers) and the company’s responses. Each entry in such a register is essentially an incident report at a strategic scale, including analysis of root cause (e.g., supplier lack of a backup facility), impact assessment, and lessons (e.g., need to dual-source critical components). Scholarly literature on strategic incident registers per se is limited, but it intersects with studies on **supply chain resilience** and **crisis management**. (Brusset and Teller, 2017) highlight that documenting supply chain disruption events and responses is key to developing resilience strategies – organizations learn which mitigation tactics worked by reflecting on past incidents. Likewise, case studies of major supply chain failures emphasize post-incident analysis as a driver for stronger contingency planning. Management-level IRS, therefore, serve as memory aids and learning tools for top management. They ensure that the organization does not ignore “black swan” events once the immediate crisis passes; instead, each major incident becomes a reference point for improving policies (such as diversifying suppliers or investing in backup IT systems). Additionally, many firms now integrate safety and incident metrics into executive dashboards – for example, *lost time injury frequency rate (LTIFR)* or number of significant supply chain incidents per quarter – to keep leadership focused on safety and risk outcomes. By treating incident occurrence as a performance metric, companies in Europe, the UK, and beyond signal a top-down commitment to continuous improvement. In summary, strategic incident reporting systems tie together the insights from the frontline IRS with the broader risk management framework, closing the loop between operational details and strategic oversight.

#### 4. Designing and Implementing an Effective IRS

Designing an incident reporting system involves both technological planning and organizational change management. An effective IRS is not just a software application; it is a socio-technical system that must align with the organization’s processes and culture. This section outlines the key stages in the IRS process and the crucial components (technical and organizational) needed at each stage.

**Stages of the Incident Reporting Process:** Researchers generally describe the incident reporting process as a cycle with several distinct stages (Diallo et al., 2024):

1. **Incident Occurrence and Detection:** An incident (accident, error, near-miss, etc.) occurs and is noticed by someone (an employee, driver, manager, or even an automated sensor in modern systems). Prompt detection is critical – organizations encourage employees to be vigilant and report *any* irregular event, no matter how small, as the first step.
2. **Report Submission:** The incident is formally reported through the IRS. This often involves filling out a standardized incident report form (nowadays usually via an app or web portal). The report captures key details: what happened, where and when, who was involved, and any immediate actions taken. A well-designed IRS provides **user-friendly reporting channels** to lower barriers to submission. For example, a mobile app may allow a truck driver to record an incident on the spot (possibly with photos) or a warehouse worker to scan a QR code at a workstation to pull up a reporting form. *Usability* is paramount: if reporting is cumbersome or time-consuming, incidents will go unreported. Studies have found that perceived complexity in reporting procedures significantly deters participation. Thus, designing intuitive interfaces and minimizing the time required (e.g., through drop-down menus, pre-filled data from sensors, etc.) is a key technical consideration.
3. **Validation and Classification:** Once a report is submitted, it typically enters a review stage for validation and categorization. Here, a supervisor or safety/risk officer checks the report for completeness and accuracy. They may classify the incident by type (safety, quality, security, etc.) and severity (e.g., near-miss, minor, major, critical). Triage is performed to decide if immediate escalation is needed – for example, a *critical* incident (like a fatal accident or major supply interruption) would trigger an emergency response and executive notification. This stage often benefits from decision-support tools: many IRS software can automatically flag certain keywords or incident types as high severity and alert the appropriate managers. Additionally, if the report is unclear, the reviewer might follow up with the reporter for clarification. A robust IRS defines clear criteria for classification to ensure consistency. Technologies like database rules and AI can assist in validation (e.g., detecting if key information is missing) and initial analysis (e.g., matching the incident to similar cases in the past).
4. **Incident Processing (Analysis and Investigation):** This is the core investigative stage. A designated team analyzes the incident to understand **root causes** and contributing factors. In logistics incidents, this might involve examining process logs, interviewing witnesses, reviewing surveillance footage, or analyzing defective parts. The outcome of this stage is an **investigation report** that details what happened and why. Importantly, this stage leads to **corrective and preventive actions (CAPA)**: recommendations on what needs to change to prevent a recurrence. For example, after investigating a warehouse pallet collapse, the team might recommend a new stacking protocol or additional rack inspections. The IRS should facilitate tracking these actions – good systems allow investigators to assign action items (with owners and deadlines) directly in the incident management software, creating accountability. In designing the IRS, one should ensure it supports attaching evidence (photos, documents), logging investigation notes, and linking to related incidents (to identify patterns). Some advanced systems integrate with analytics tools to find trends – for instance, clustering incidents by location or time to reveal hidden patterns. **Figure 1** illustrates a generalized workflow of incident handling, including decision points for classification and investigation, and feedback loops for learning.

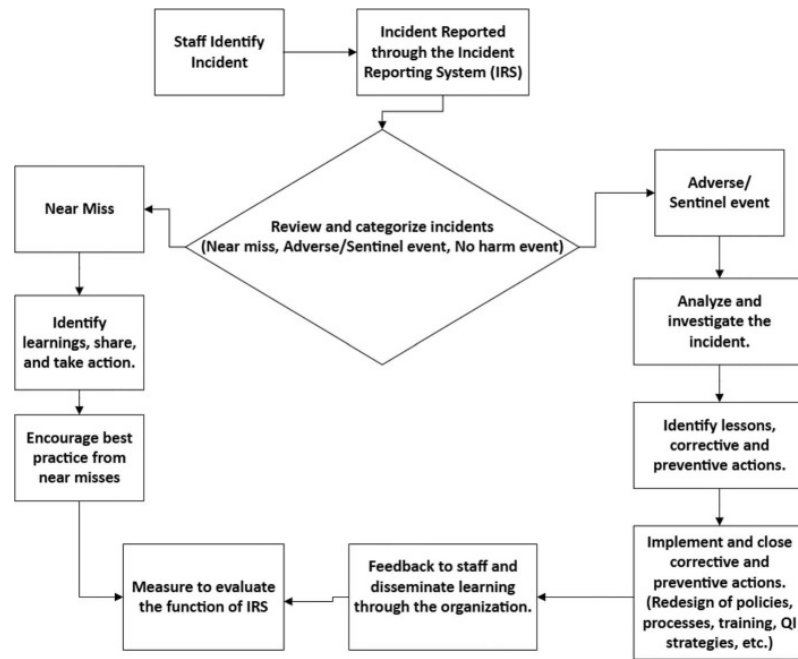


**Figure 1:** Workflow of a typical Incident Reporting System – Source (Kumah et al., 2024)

5. **Resolution and Implementation of Actions:** After analysis, the recommended corrective actions must be implemented. This stage might technically lie outside the reporting system, but a mature IRS tracks the closure of incidents through to completion of actions. Many enterprises IRS are configured to keep an incident “open” in the system until all follow-up actions are completed and verified. For example, if an incident report mandates new safety training, the IRS might track whether that training was delivered to all employees, only then marking the incident as resolved. Implementation often requires management support and resources – one reason why **top management commitment** is cited as a critical success factor for IRS. Without leadership ensuring that recommended changes are actually made, the IRS can devolve into a “reporting for reporting’s sake” exercise. Therefore, organizational protocols should tie incident reviews to management review meetings and budgeting (e.g., allocating funds for safety improvements identified).
6. **Evaluation and Learning:** The final stage of the cycle is reflective. Data from incidents are aggregated and analyzed over time to identify trends, measure the effectiveness of interventions, and share lessons learned organization-wide. This might involve monthly or quarterly incident review boards, dashboards of key metrics, and newsletters or safety alerts that disseminate insights. A hallmark of a strong IRS is a feedback loop: reporters and frontline staff are informed of outcomes (“what was done about the incident”), and lessons are fed into training programs. For instance, after a root cause analysis finds that a routing error caused a delivery delay, a memo might be sent to all dispatchers with guidance on the new procedure. Evaluation also includes assessing the IRS itself – tracking reporting rates, timeliness of investigations, and user feedback. Diallo et al. (2024) highlight that effective IRS requires mechanisms for “*post-reporting follow-up*” and user feedback, which can incentivize greater engagement in reporting. Organizations may perform audits of their incident reports to ensure issues aren’t slipping through unreported, indicating where more awareness or training is needed.

**Technological Components:** An IRS is underpinned by technology, especially in large-scale logistics operations. Key components include:

- **Incident Database:** a central repository (often cloud-based) where all incident records are stored. This must be secure (to protect sensitive data) and structured to allow querying and analysis. Modern systems use relational databases or NoSQL stores with web interfaces. Blockchain has even been proposed for IRS to ensure tamper-proof records and transparency, though traditional databases remain the norm.
- **User Interface:** the reporting and management front-end. This could be a web portal accessible on desktop and mobile, or a dedicated mobile app. The UI should support multiple languages, offline reporting if needed, and accessibility considerations. Some systems incorporate OCR (optical character recognition) to auto-fill details from scanned forms or IoT integration.
- **Notification System:** integrated communication tools that send alerts (email, SMS, or in-app notifications) to relevant parties when an incident is reported or when an investigation is due. Automatic escalation rules ensure, for example, that a critical incident pages the on-call emergency team immediately.
- **Analytics and Reporting Tools:** dashboards that allow safety managers to slice and dice incident data by date, location, category, etc. Many IRS software come with built-in analytics or allow exporting data to business intelligence tools. Advanced analytics can include trend charts, such as incident rate over time, heat maps like incident frequency by warehouse, and predictive analytics. As AlMarri et al. (2025)<sup>5</sup> note, integrating historical incident data enables continuous improvements and proactive risk mitigation through trend analysis.
- **Integration APIs:** the IRS should ideally interface with other enterprise systems, for instance HR systems to pull employee info for incident reports, maintenance systems, or procurement management systems. Integration ensures the IRS is woven into daily operations rather than isolated. For example, Oracle's EHS module integrates incident reporting with corrective action tracking and regulatory reporting requirements. In one case, SAP's incident management allowed automatic creation of a case in the maintenance module when "equipment failure" was selected as the cause, streamlining the response.

**Organizational and Human Factors:** Technology alone does not guarantee an effective IRS. Cultural and process factors are repeatedly highlighted in studies:

- **Management Commitment:** Leadership must visibly support the IRS. This means allocating time to discuss incidents in meetings, not penalizing employees for reporting bad news, and providing resources to implement fixes. Top management commitment was identified as a prerequisite for successful incident reporting in multiple studies<sup>2</sup>. When executives champion the IRS as a tool for improvement and not a blame tool, employees are more likely to participate honestly.
- **Training and Awareness:** Employees and supply chain partners need to be trained on *how* and *why* to report incidents. Training should cover what kinds of events to report, how to use the reporting tools, and assurances about the no-blame policy. Regular refreshers and sharing of success stories can motivate ongoing participation. If new technology is introduced, hands-on training is essential to avoid frustration.
- **No-Blame Culture and Anonymity:** A "*just culture*" (Dekker, 2016), where individuals feel safe reporting mistakes or problems, is critical. If the IRS is perceived as a surveillance or punishing tool, under-reporting will result. Organizations increasingly adopt non-punitive reporting policies, separating the act of reporting from any disciplinary process, except in cases of willful misconduct. Some IRS allow anonymous reporting to lower fear, though anonymity can limit follow-up; a balance is often struck by guaranteeing confidentiality and focusing on systemic causes rather than individual blame.

- **Feedback and Recognition:** Providing feedback to reporters is an often-cited best practice. It closes the loop and reinforces the value of reporting. Some companies even incorporate incident reporting into performance recognition. Conversely, a lack of feedback is a common complaint that can undermine an IRS.
- **Incentives and Accountability:** While one should not “bribe” people to report, smart incentive structures can help. This can be as simple as including reporting participation as part of managerial KPIs or ensuring that zero reported incidents is not automatically assumed to mean perfect absence of losses. On the accountability side, clear assignment of roles (who investigates, who approves closure, etc.) and deadlines keep the system responsive. Many firms use Service Level Agreements (SLAs) for incident management; for instance, all incident reports must be initially reviewed within 24 hours, investigations must be completed within 10 days, etc., to instill discipline.
- **Continuous Improvement of the IRS:** Lastly, the IRS design itself should be iterative. User feedback should be solicited to improve forms or workflows. If analysis finds that certain types of incidents are often reported with missing information, the form can be adjusted to prompt for that detail. In essence, managing the IRS is like a living process that ensures it remains effective and user-friendly over time.

In summary, designing an effective IRS in logistics/SCM requires marrying a clear, streamlined technical system with a supportive organizational environment. Key design stages, from reporting and validation to investigation and learning, must be enabled by well-thought-out tools and practices. When done properly, employees at all levels treat incident reporting and review as a normal, valued aspect of work, leading to a safer and more resilient supply chain.

## 5. Added Value of Incident Reporting Systems

This section discusses the added value of IRS, supported by empirical studies and real-world examples from different regions and sectors.

**Enhancing Safety and Reducing Accidents:** The clearest benefit of an IRS is improved safety outcomes. By learning from past incidents, companies can prevent future accidents. Peer-reviewed studies, especially in safety-critical industries, provide evidence of this effect. Petschnig and Haslinger-Baumann’s review (2017)<sup>2</sup> found a “*close correlation between the establishment of [incident reporting] and patient safety*” in healthcare settings. In other words, hospitals that implemented incident reporting saw measurable improvements, although quantifying the exact impact is complex. Translating this to logistics, a similar correlation is expected: firms with systematic incident reporting and learning mechanisms tend to have lower accident rates over time than those without. McLean et al. (2022)<sup>1</sup> evaluated a new IRS in the Australian outdoor adventure sector. They found the system to be effective for improving safety, noting that “*a key strength of [the IRS] is its effectiveness as an incident reporting tool for improving safety*” in that sector. Participants perceived that collecting and analyzing incident data led to safer practices and raised awareness of risks. This aligns with broader industrial experience in that many companies report significant drops in injury rates after introducing IRS as part of their Safety Management Systems. For example, Alcoa, under the leadership of CEO Paul O’Neill (1987–1999), implemented a rigorous safety and incident reporting program that became a benchmark for industrial safety (Duhigg, 2012). The company emphasized reporting all incidents, including near-misses, to identify and mitigate risks.

In the **trucking and transportation** domain, voluntary reporting of near-misses and hazards has been linked to accident reduction. While truck fleet safety studies often focus on interventions like training or telematics, reporting culture is a known factor. One recent study in a European trucking context found that companies with more developed *reporting and feedback practices* tended to achieve lower

accident frequencies. The mechanism is intuitive: more reports provide more opportunities to fix problems, thereby preventing accidents. Gao et al. (2021) offer a compelling longitudinal example from the **aviation sector**: the U.S. **Aviation Safety Reporting System (ASRS)**, a voluntary incident reporting program, has collected over 1.6 million reports since 1975 and has “*contributed to the efficiency and safety improvement*” of U.S. aviation. Their time-series analysis confirmed that after accidents occur, there is often a spike in safety reports (as people become more alert), and the knowledge captured helps break the chain of future accidents. Commercial aviation in the USA now has one of the world’s lowest accident rates, and confidential incident reporting (through ASRS and airline programs) is widely credited as a key contributor to that success. This example, though not in logistics per se, underscores how a mature IRS can drive a continuous cycle of safety improvements in any field involving complex operations.

**Operational Continuity and Risk Management:** Beyond safety, IRS contributes to overall supply chain *resilience* and reliability. By systematically logging incidents like equipment breakdowns, IT system outages, or supplier failures, organizations build a knowledge base of vulnerabilities. This supports risk management in several ways. First, it enables **trend analysis**. Second, it improves **response efficiency** when incidents do happen. With an IRS in place, companies often develop playbooks for common incident types. Through incident reports, they can identify root causes and reconfigure their processes, avoiding a potential significant disruption, especially during peak seasons (Kembro and Norrman, 2020). There is thus evidence of tangible operational gains that an IRS can provide regarding fewer disruptions and faster recovery.

Incident reporting also adds value by strengthening **regulatory compliance** and **corporate accountability**. In the EU, for instance, regulations like the Seveso III Directive for hazardous materials logistics require companies to report certain incident types to authorities and demonstrate learning. An internal IRS helps gather the information needed for such compliance reports systematically. Moreover, establishing a robust incident reporting and improvement process can protect companies legally and reputationally. If an accident does occur, being able to show regulators that “we have an established system to report and address incidents, and here is the history of improvements we’ve made” can lead to more favorable assessments than if a company appears negligent or unaware of prior warnings.

**Safety Culture and Employee Morale:** An often underappreciated benefit of IRS is the positive impact on organizational culture. When employees see that management takes incident reports seriously, trust and communication improve. This fosters a *proactive safety culture* where everyone feels responsible for spotting and addressing issues. Empirical research supports this cultural benefit. A study in Australia examined safety culture before and after implementing an IRS in outdoor recreation organizations. They found significant improvements in the “*communication and feedback*” dimension of safety culture: staff reported feeling more empowered to speak up about hazards, and management became more transparent in discussing safety matters (Goode et al., 2019). In logistics, where front-line workers often have critical knowledge of day-to-day risks, empowering them through reporting can unlock that knowledge for the organization.

**Challenges and Ensuring Value Realization:** It should be acknowledged that not all incident reporting systems automatically produce benefits; literature notes challenges that can limit value if not addressed. One challenge is **under-reporting** – if incidents are not reported, the organization loses learning opportunities. Studies have identified fear of blame and lack of time as the main barriers to reporting<sup>11</sup>. Thus, the added value of an IRS is maximized only when there is high. Another issue is **data overload** – organizations can drown in reports if they lack resources to process them. A European study (van der Schaaf, 1992) on incident databases warned that collecting data without analysis is futile; value comes from extracting actionable insights. Therefore, companies must invest in analysis capability to reap benefits. Nevertheless, even if the exact ROI is hard to calculate, the

consensus in research and practice is that a well-functioning IRS is a cornerstone of risk management and safety excellence.

**Global and Regional Perspectives:** Across different regions, the value of IRS in logistics/SCM is recognized, though the emphasis may vary. In the **United States**, there is a strong link with legal compliance – companies see IRS as part of OSHA compliance for workplace safety and also as a defense mechanism against litigation. Many U.S. firms participate in industry safety programs where sharing incident data (anonymously) helps raise standards across the sector. In **Europe and the UK**, incident reporting is often tied to formal management systems standards like ISO 45001, which explicitly require processes for incident reporting and investigation. European logistics companies, especially in sectors like chemicals or aviation cargo, also benefit from government or industry-sponsored reporting schemes. These frameworks amplify the value of internal IRS by contributing to broader safety knowledge. In **Australia**, as evidenced by the work of McLean et al. and others, there is increasing academic and industry attention to developing tailored IRS for sectors like mining, transport, and outdoor operations, often with a focus on human factors and usability to ensure these systems truly get used and learned from.

One emerging area of value is leveraging IRS data for **predictive analytics**. With enough historical incident data, machine learning models can potentially predict where and when incidents are likely to occur. A recent study in *Safety Science* (Thallapureddy et al., 2024) suggested that the biggest bottleneck in effective incident prevention is often the *lack of reporting* – hence, improving reporting frequency and data quality is the key to unlocking predictive safety models. This suggests that the full future value of IRS may grow as organizations accumulate rich datasets and apply advanced analytics, moving from reactive learning to *proactive prevention*.

In conclusion, numerous studies and empirical research support that incident reporting systems, when properly implemented, add significant value to logistics and supply chain management. They reduce accidents and downtime, improve regulatory compliance, strengthen the safety culture, and ultimately contribute to a more resilient and efficient supply chain.

## 6. Conclusions

Incident reporting systems have become a valuable element of logistics and supply chain management, underpinning the continuous improvement of safety and risk management practices. This paper defined IRS in the SCM context as structured mechanisms for capturing and learning from operational disruptions, and it categorized various types of IRS from enterprise-wide systems to specialized accounting, logistics, and management-focused tools. Designing an effective IRS requires careful attention to process stages, from user-friendly reporting through rigorous investigation and feedback loops, and to cultural enablers like a no-blame ethos and leadership support. When these systems are well-designed and embraced, the evidence shows they yield substantial added value: fewer accidents and injuries, reduced downtime and losses, better regulatory compliance, and a stronger organizational culture of safety and accountability.

In scholarly terms, IRS contributes to what researchers call *organizational resilience* and *learning from events*. By systematically converting incident experiences into knowledge, firms transform immediate failures into long-term success factors. Moreover, as supply chains grow more complex and technologies like IoT and AI become integrated, incident reporting is evolving, but its core purpose remains the same, which is enabling human learning and response. Future research could explore quantitative links between IRS implementation and supply chain performance metrics, or how to best incentivize reporting in different cultural settings. Likewise, practitioners should continue sharing the best practices on IRS usability and integration, ensuring these systems are not seen as mere check-the-box compliance tools but as dynamic instruments for change. Ultimately, the organizations that thrive in the face of uncertainty will be those that effectively *learn from every*

*incident*, turning each mishap into an opportunity for improvement. Incident reporting systems, as discussed, provide the backbone for that learning process in logistics and supply chain management.

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# Applications of skyline and top- $k$ dominating queries on economic, sustainability, environmental and other data

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## Abstract

This paper presents the applications of skyline and top- $k$  dominating queries on several problems and contexts with economic, sustainability and environmental data, in order to demonstrate their simplicity and their power for finding optimal choices, without the need for using complex multi-criteria algorithms and techniques. The presented applications mainly focus on the problem of countries' ranking by economic, sustainability and environmental criteria, as it is a problem with major difficulties that has gained a lot of attention from the researchers, who have proposed only specialized and complex methods. The results show that we can quickly detect candidate countries with optimal economic performance, or sustainable growth, or low-income inequality, or any other desired combination of a user-selected set of criteria. To the knowledge of the authors, this paper is the first to propose this methodology on economic, sustainability and environmental data, which can be extensively applied to many other multi-criteria problems and applications.

**Keywords:** *skyline queries, top- $k$  dominating queries, economic data, sustainability data, environmental data*

## 1. Introduction

Skyline and top- $k$  dominating queries belong to a special type of queries in databases named preference-based queries. They are based on the notion of domination between the objects of a dataset, where each object is represented by  $d$  attributes / characteristics / dimensions (it is considered as a  $d$ -dimensional object). More specifically, we accept that an object dominates another object, when it has a better or equal value in all dimensions, and it has a strictly better value in at least one dimension.

Skyline queries return all objects that are not dominated by others. They have been proposed in (Borzsonyi, Kossmann and Stocker, 2001), and since then, they have received great attention. They have been used in a wide range of applications and studies, in many multi-criteria decision support

systems. Furthermore, a lot of skyline query variants have been proposed in the literature. For example, they have been studied in distributed environments (Hose and Vlachou, 2012), in data streams (Mohamud et al, 2023), in data-specific applications (Gothwal, Choudhary and Singh, 2018), on incomplete data (Gulzar et al, 2017), and in many other environments. Detailed surveys are available in (Papadopoulos et al. 2020; Kalyvas and Tzouramanis, 2017; Tiakas, Papadopoulos and Manolopoulos, 2015a).

Top- $k$  dominating queries consider the number of objects that an object dominates (i.e., the dominance score), and they return the  $k$  objects with the best dominance scores. They have been proposed in (Papadias et al, 2005), and since then, they have been also used in several ranking applications and studies. For example, they have been studied in multi-dimensional data (Yiu and Mamoulis, 2007; Yiu and Mamoulis, 2009), in subspaces (Tiakas, Papadopoulos and Manolopoulos, 2011), in metric spaces (Tiakas et al, 2016), in distributed environments (Amagata et al, 2016), on incomplete data (Miao et al, 2015; Wu et al, 2022), and in many other environments. Detailed surveys are available in (Papadopoulos et al. 2020; Tiakas, Papadopoulos and Manolopoulos, 2015b).

However, to the best of the authors' knowledge, skyline and top- $k$  dominating queries have not been systematically applied on economic contexts and problems, that are focused on finding optimal choices in multicriteria analyses. A first example application, but only for top- $k$  dominating queries, was presented in (Tiakas, 2023). In this new paper, the authors applied both skyline and top- $k$  dominating queries on contexts with economic, sustainability and environmental data for finding optimal choices. Moreover, the changes in the results for those queries in time were studied. The results were interesting and demonstrated the advantages of skyline and top- $k$  dominating queries, where there is no need for using complex multi-criteria algorithms and techniques or using weights and other kinds of parameters. Furthermore, the results can provide quick hints and optimal choices for the researchers to focus on and perform further examination with other methods.

The problem that we selected to apply the queries on, under the mentioned contexts, is the country ranking problem, which also gained a lot of attention from the researchers, as it has important difficulties. One of the first approaches for ranking countries with socio-economic indicators was presented in (Peniwati and Hsiao, 1987). More composite indicators were proposed in (Munda and Nardo, 2003). A clustering and ranking approach was also proposed in (Cavusgil, Kiyak and Yeniyurt, 2004). More specific measures and indices were proposed in (Malul, Hadad and Ben-Yair, 2009; Mehrara and Zirak, 2013; Li et al, 2014), and even more specialized methods have been proposed in (Blanden, 2013; Antanasijević et al, 2017). However, all these methods are sensitive to the parameters, weights, measures and indices that they use, and have a significant complexity. Moreover, they are designed with specific criteria and contexts, thus they cannot be applied easily to different contexts or use different criteria. The skyline and top- $k$  dominating queries do not have these issues and can be applied in many other multi-criteria contexts and problems, and even on different domains (not only for country ranking).

## 2. Skyline and top- $k$ dominating queries

### 2.1 Basic concepts

As already mentioned, both skyline and top- $k$  Dominating Queries are based on the notion of a domination relationship between the objects of a dataset. Specifically, let  $U$  be a dataset that contains  $d$ -dimensional objects, where each dimension expresses a different attribute / characteristic of the objects. Let also two different objects  $a, b$  of  $U$  that have the values  $a_1, a_2, \dots, a_d$  and  $b_1, b_2, \dots, b_d$  in their corresponding dimensions. The only assumption that must be taken is that on each used dimension there is a total order for the values in its domain, i.e., if  $a_i$  and  $b_i$  are two random values from the domain of the  $i$ -th dimension, it holds  $a_i < b_i$  or  $a_i = b_i$  or  $a_i > b_i$ . Practically, this means that

it is clear what is considered better in the values of a specific dimension. Most of the used attributes/characteristics in analyses and studies of objects have already that property.

Now, in a specific dimension we may prefer smaller attribute values, but in another dimension, we may prefer larger attribute values. For example, in economic analysis we prefer a country with a large GDP but with a small inflation rate and a small unemployment rate. Therefore, let  $D_1, D_2$  two subsets of the dimensions set  $D = \{1, 2, \dots, d\}$ , which satisfy the conditions  $D_1 \cup D_2 = D$  and  $D_1 \cap D_2 = \emptyset$ , and where in the dimensions of  $D_1$  we prefer smaller attribute values but in the dimensions of  $D_2$  we prefer larger attribute values. In the following we provide a more general definition for the notion of domination to cover all those cases.

**Definition-1:** We define that an object  $a$  *dominates* another object  $b$ , and we denote this as  $a < b$ , if and only if  $a$  has a better or equal value in all  $D = D_1 \cup D_2$  dimensions from  $b$ , and  $a$  has a strictly better value in at least one dimension, where in the dimensions of  $D_1$  smaller values are preferred and in the dimensions of  $D_2$  larger values are preferred, i.e.:

$$a < b \Leftrightarrow (\forall i \in D_1: a_i \leq b_i \text{ and } \forall j \in D_2: a_j \geq b_j) \\ \text{and } (\exists i \in D_1: a_i < b_i \text{ or } \exists j \in D_2: a_j > b_j)$$

The skyline query in a dataset returns all objects of the dataset that are not dominated by any other objects. More formally, we have the following definition:

**Definition-2:** A skyline query in a dataset  $U$  that contains  $d$ -dimensional objects, returns the subset  $S$  of all objects that are not dominated in  $U$ , i.e.,  $S = \{a \in U \mid \nexists b \in U : b < a\}$ .

The top- $k$  dominating query considers a simple and naïve scoring function that counts how many objects an object dominates. More formally, we have the following definition:

**Definition-3:** The dominance score of an object  $a$  in a dataset  $U$  that contains  $d$ -dimensional objects, which is denoted as  $dom(a)$ , is the number of objects that the object  $a$  dominates in  $U$ , i.e.,  $dom(a) = |\{b \in U : a < b\}|$ .

The top- $k$  dominating query returns the  $k$  objects of the dataset with the best dominance scores. More formally, we have the following definition:

**Definition-4:** A top- $k$  dominating query in a dataset  $U$  that contains  $d$ -dimensional objects, returns the subset  $T$  of  $k$  objects with the highest dominance scores in  $U$ , in a descending order, i.e.,  $T = \{a_1, a_2, \dots, a_k \in U \mid (\nexists b \in U : dom(b) > dom(a_1) \text{ or } dom(b) > dom(a_2) \text{ or } \dots \text{ or } dom(b) > dom(a_k)) \text{ and } (dom(a_1) \geq dom(a_2) \geq \dots \geq dom(a_k))\}$ .

## 2.2 An example with real data

To illustrate and understand all previous definitions we present a simple and concrete example with real data, derived from the World Bank Open Data (World Bank Open Data, 2025). We want to analyze the economic performance of Euro Area Countries, with respect to inflation and unemployment rates, as recorded for the most available recent year (2023) in World Development Indicators Data Bank (World Development Indicators DataBank, 2025), and in its most recent update (03/24/2025). Table 1 depicts the corresponding data derived for our example: country codes and names of the Euro Area, unemployment rates (% of total labor force), and inflation GDP deflator rates (annual %).

Table 1: Economic performance data for Euro Area countries in 2023

| Country Code | Country Name | Unemployment (% of total labor force) | Inflation. GDP deflator (annual %) |
|--------------|--------------|---------------------------------------|------------------------------------|
| AUT          | Austria      | 5,264                                 | 6,647653416                        |

|     |                 |        |             |
|-----|-----------------|--------|-------------|
| BEL | Belgium         | 5,528  | 4,508102849 |
| HRV | Croatia         | 6,086  | 11,74033063 |
| CYP | Cyprus          | 6,098  | 3,82970232  |
| EST | Estonia         | 6,378  | 8,054783147 |
| FIN | Finland         | 7,151  | 3,913517347 |
| FRA | France          | 7,335  | 5,303571753 |
| DEU | Germany         | 3,068  | 6,14291653  |
| GRC | Greece          | 11,066 | 5,874562668 |
| IRL | Ireland         | 4,288  | 3,621871537 |
| ITA | Italy           | 7,627  | 5,81875394  |
| LVA | Latvia          | 6,465  | 6,406916526 |
| LTU | Lithuania       | 6,841  | 9,021755817 |
| LUX | Luxembourg      | 5,184  | 3,430024562 |
| MLT | Malta           | 3,11   | 5,304718766 |
| NLD | Netherlands     | 3,537  | 7,343742685 |
| PRT | Portugal        | 6,509  | 6,902365903 |
| SVK | Slovak Republic | 5,84   | 10,13649125 |
| SVN | Slovenia        | 3,652  | 10,05010575 |
| ESP | Spain           | 12,179 | 6,235280039 |

Figure 1 depicts the corresponding countries as two-dimensional points, where the dimensions are the criteria that we want to study (unemployment rate and inflation rate). In both dimensions we have real numbers and it is clear that smaller values are preferred. Therefore, the skyline query returns the countries that are not dominated by other countries with respect to the aforementioned criteria, i.e.,  $S = \{\text{Germany, Malta, Ireland, Luxembourg}\}$ . We illustrated the skyline with red color in Figure 1.

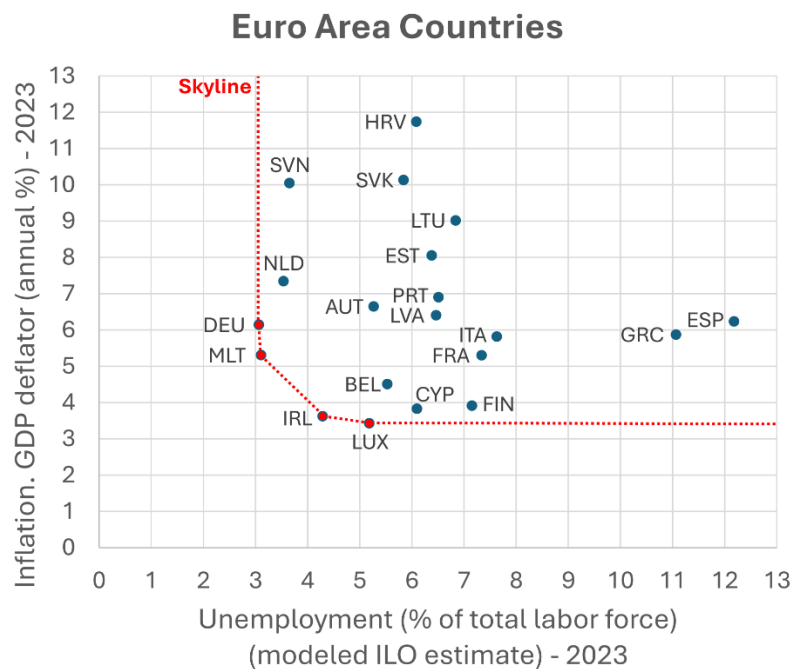


Figure 1: Skyline of Euro Area countries for our example

In the next step, we calculate all dominance scores for the Euro Area countries, according to the previous definitions. Table 2 presents the score results in a descending order.

Table 2: Dominance scores of Euro Area countries for our example

| Country Name | Dom. Score | Country Name    | Dom. Score |
|--------------|------------|-----------------|------------|
| Luxembourg   | 14         | Slovenia        | 2          |
| Ireland      | 14         | Latvia          | 2          |
| Malta        | 12         | Italy           | 2          |
| Germany      | 10         | Slovak Republic | 1          |
| Belgium      | 10         | Portugal        | 1          |
| Cyprus       | 9          | Greece          | 1          |
| Netherlands  | 5          | Estonia         | 1          |
| Austria      | 5          | Croatia         | 0          |
| Finland      | 4          | Lithuania       | 0          |
| France       | 3          | Spain           | 0          |

It is interesting to note that Belgium is not a skyline country (as it is dominated by Ireland and Luxembourg), but its dominance score is equal to that of Germany which is a skyline country. A top-5 dominating query would return  $T = \{\text{Luxembourg, Ireland, Malta, Germany, Belgium}\}$ . Therefore, both skyline and top- $k$  dominating queries can quickly provide useful information for optimal choices and further study.

In order to faster calculate the dominance score  $dom(a)$  of an object  $a$  (when we have two dimensions and smaller values are preferred, as in our example), we can take the rectangular area defined by all points with  $(x, y)$  values that are greater or equal to the coordinates of  $a$ . This area is called the dominance region of object  $a$ . Figure 2 illustrates the dominance regions of Germany and Belgium for our example, in which we can validate that each one dominates 10 other countries that are inside those areas, i.e.,  $dom(\text{DEU}) = 10$  and  $dom(\text{BEL}) = 10$ .

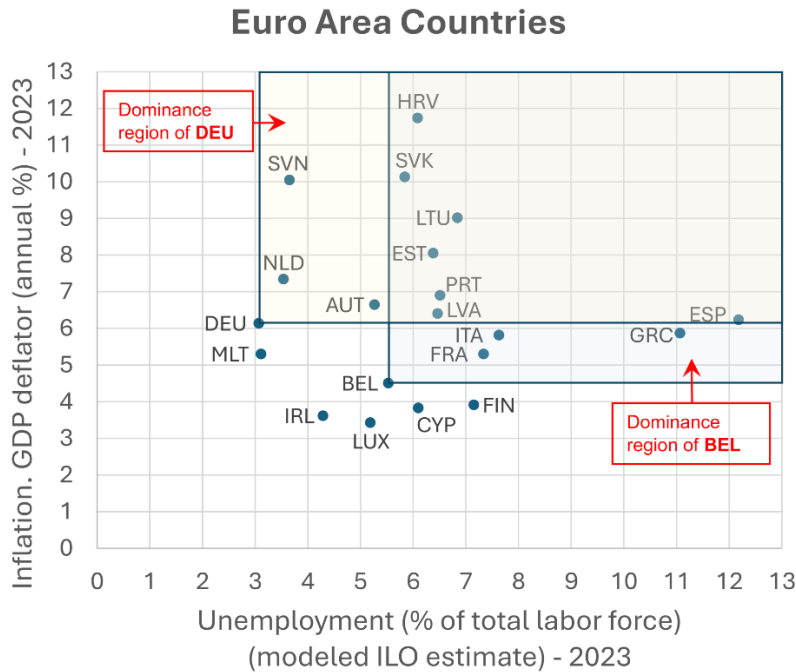


Figure 2: Example of dominance regions

### 2.3 Advantages and disadvantages of skyline and top- $k$ dominating queries

In the previous example we saw that both skyline and top- $k$  dominating queries can provide useful results for optimal choices in such multi-criteria problems, because a good choice may appear in the

results of a top- $k$  dominating query, but not in the results of a skyline query. In this subsection, we further present the advantages and disadvantages of those queries.

Skyline queries return all optimal choices without the need of any scoring function. They are using the total ordering of the values in each dimension to provide a simple and natural domination check rule. There is no need to apply weights and parameters to the studied dimensions or even to transform their values into other domains, as it is clear what is considered better to each specific dimension due to the total order. This is extremely useful especially when preference weights are unknown or even cannot be agreed upon. The results of skyline queries are fair and transparent, as all returned points are "non-dominated", which makes the decision-making fair.

However, skyline queries do not provide ranking. They do not tell which among the skyline objects is "better", they only ensure non-domination. Another problem is that the result set size is unbounded, thus it may return many objects. Furthermore, they are sensitive to outliers, as a single extreme point can dominate many reasonable alternatives.

Top- $k$  dominating queries always return exactly  $k$  optimal results, which is easier to present or work with. The results are sorted according to the dominance scores, giving a clear ranking. The users can preselect the  $k$  value, or they can run the queries incrementally and stop in the desired number of results. Only the simple count of dominations is required for computing the dominance scores, and no other ranking function or calculation is required. Again, there is no need to apply weights and parameters to the studied dimensions or even to transform their values into other domains. Top- $k$  dominating queries provide efficient decision-making when we want a few "strongest" choices based on dominance. Moreover, they provide more predictable and concise output compared to skylines.

However, Top- $k$  dominating queries may miss some skyline points that do not dominate many others, thus it may get excluded from the results. In addition, the dominance counting procedure in large datasets can be computationally expensive, thus it must be optimized.

An important issue that must be considered for both queries is the number of the selected dimensions. It has been proven that, when we increase the number of dimensions, the probability of an object to dominate another object becomes smaller. This has the effect of lowering the dominance scores in top- $k$  dominating queries and increasing the number of objects in the results of skyline queries. Especially in high-dimensional data, the number of skyline results may be huge. In the study of (Tiakas, Papadopoulos and Manolopoulos, 2013), there is a dimension  $d_0$  from which on, all data objects will be included in the skyline, because no object will dominate any other. This dimension is called eliminating dimension and can be approximated by the formula:  $d_0 \approx 2[\ln N] + 2$ , where  $N$  is the total number of objects in the dataset. For example, for  $N = 10, 50, 100, 1000, 10000, 100000, 1000000$  we derive 8, 10, 12, 16, 22, 26, 30, respectively. Thus, in a dataset with 1000 objects and dimensionality greater than 16, almost all of its objects will be included in the skyline, and all dominance scores will be almost zero.

As a conclusion, we propose the following methodology. We first apply skyline queries to derive quick hints and optimal choices. Then we apply top- $k$  dominating queries to further investigate the dominance scores and take ranked results. Both queries may be proven useful as top- $k$  dominating queries may miss some skyline objects. We keep the number of the selected dimensions relatively small, to overcome the dimensionality issues. If we have many different criteria/dimensions that we want to study for the objects of a dataset, we could apply the skyline and top- $k$  dominating queries in the full dimension set, but the results provided by splitting in subsets of dimensions (grouping the criteria) would be much more informative.

### 3. Applications on economic, sustainability and environmental data

In this section we will present applications of skyline and top- $k$  dominating queries on problems and contexts with economic, sustainability and environmental data for finding optimal choices. We will analyze performance and ranking of the world countries to specific interesting contexts. All of 205 recorded countries data was derived from the World Bank Open Data (World Bank Open Data, 2025) and the World Development Indicators Data Bank (World Development Indicators DataBank, 2025), in its most recent update (03/24/2025). Moreover, in each case study, we applied skyline and top- $k$  dominating queries in the range of five last recorded years to the databases, in order to study the changes of their results during time, which was also even more interesting. The selected range was from 2019 to 2023, including the Covid years.

#### 3.1 Finding countries with optimal economic performance

In this case study we want to identify countries that outperform their peers in terms of GDP per capita, unemployment rate, and inflation rate. Skyline and top- $k$  dominating queries will return a list of countries that provide the highest GDP per capita combined with the lowest unemployment and inflation, identifying countries with optimal economic performance. These countries stand out in their region and may be considered as leading economic models or emerging economies.

A summary of the applied criteria / dimensions follows:

- *GDP per capita (higher values are better)*. For this factor we used the “GDP per capita (current US\$)” from World Development Indicators Data Bank, which is GDP divided by midyear population of countries in current US\$. The higher the GDP per capita is, the wealthier the people in the country are (as each person on average produces more).
- *Unemployment rate (lower values are better)*. For this factor we used the “Unemployment, total (% of total labor force) (modeled ILO estimate)” from World Development Indicators Data Bank, where the ILO estimate provides a complete set of internationally comparable labor statistics, including both nationally reported observations and imputed data for countries with missing data.
- *Inflation rate (lower values are better)*. For this factor we used the “Inflation, GDP deflator (annual %)” from World Development Indicators Data Bank, where GDP deflator accounts for all goods and services produced domestically. This makes it a broader and more accurate measure of inflation within the economy.

Table 3 presents the results for the skyline queries in alphabetical order for the years 2019 to 2023. It is interesting that some countries like Luxemburg, Monaco, Norway, Qatar, Switzerland are constantly reported as skyline countries in all five years. Furthermore, there are several other countries that are reported in the results but only in some years. It is also interesting that we have less results during the covid years (2019, 2020) in comparison with the next two years.

Table 3: Results of skyline queries for GDP per capita, unemployment rate, inflation rate

|      |                                                                                                                                                                                                                                                                                                           |
|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2019 | Bermuda, Iceland, Luxembourg, Monaco, Nauru, Norway, Qatar, Switzerland.                                                                                                                                                                                                                                  |
| 2020 | Bermuda, Guyana, Ireland, Kuwait, Luxembourg, Monaco, Netherlands, Norway, Qatar, Singapore, Switzerland, Timor-Leste.                                                                                                                                                                                    |
| 2021 | Aruba, Bahamas, Bahrain, Bermuda, Cambodia, Czechia, Fiji, Germany, Ireland, Israel, Japan, Luxembourg, Moldova, Monaco, Netherlands, Norway, Qatar, Singapore, Solomon Islands, St. Kitts and Nevis, Switzerland, Thailand, United Arab Emirates, United Kingdom.                                        |
| 2022 | Bahrain, Bermuda, Cambodia, Germany, Ireland, Israel, Japan, Kiribati, Kuwait, Luxembourg, Malta, Marshall Islands, Mauritania, Moldova, Monaco, Nauru, Netherlands, New Zealand, Norway, Qatar, Singapore, Solomon Islands, Switzerland, Thailand, Tonga, United Arab Emirates, United States, Viet Nam. |
| 2023 | Brunei Darussalam, Iraq, Ireland, Luxembourg, Monaco, Norway, Qatar, Singapore, Switzerland, Timor-Leste.                                                                                                                                                                                                 |

Table 4: Results of top-50 domination queries for GDP per capita, unemployment rate, inflation rate

|     | 2019            |       | 2020            |       | 2021          |       | 2022            |       | 2023            |       |
|-----|-----------------|-------|-----------------|-------|---------------|-------|-----------------|-------|-----------------|-------|
| Top | Country         | Score | Country         | Score | Country       | Score | Country         | Score | Country         | Score |
| 1   | Qatar           | 195   | Qatar           | 186   | Japan         | 150   | Japan           | 145   | Qatar           | 191   |
| 2   | United Arab Em. | 158   | Bahrain         | 144   | Switzerland   | 122   | Korea. Rep.     | 135   | United Arab Em. | 151   |
| 3   | Singapore       | 144   | Singapore       | 133   | Malta         | 119   | Switzerland     | 120   | Kuwait          | 148   |
| 4   | Kuwait          | 132   | Kuwait          | 133   | Un. Kingdom   | 118   | Malta           | 110   | Bahrain         | 147   |
| 5   | Bahrain         | 132   | United Arab Em. | 131   | Germany       | 112   | Israel          | 106   | Norway          | 141   |
| 6   | Japan           | 131   | Norway          | 130   | Korea. Rep.   | 111   | New Zealand     | 99    | Singapore       | 137   |
| 7   | Oman            | 130   | Oman            | 126   | Netherlands   | 106   | Germany         | 98    | Switzerland     | 117   |
| 8   | Norway          | 130   | Switzerland     | 116   | Israel        | 106   | United Kingdom  | 95    | Korea. Rep.     | 116   |
| 9   | Switzerland     | 117   | Ireland         | 106   | Ireland       | 96    | Netherlands     | 93    | Saudi Arabia    | 107   |
| 10  | Korea. Rep.     | 112   | Japan           | 105   | Denmark       | 96    | Bahrain         | 88    | Oman            | 104   |
| 11  | Trinidad-Tobago | 107   | Trinidad-Tobago | 99    | Czechia       | 96    | Austria         | 86    | Denmark         | 104   |
| 12  | United States   | 94    | Thailand        | 94    | Slovenia      | 93    | Luxembourg      | 83    | Japan           | 101   |
| 13  | Germany         | 93    | Israel          | 94    | Thailand      | 92    | United States   | 81    | United States   | 99    |
| 14  | Malaysia        | 89    | Germany         | 87    | New Zealand   | 86    | Thailand        | 81    | Trinidad-Tobago | 98    |
| 15  | Israel          | 87    | Brunei Darus.   | 83    | Australia     | 85    | Australia       | 78    | Brunei Darus.   | 98    |
| 16  | United Kingdom  | 85    | Korea. Rep.     | 82    | Austria       | 83    | Puerto Rico     | 75    | Ireland         | 94    |
| 17  | Denmark         | 83    | Netherlands     | 79    | Belgium       | 75    | Slovenia        | 74    | Thailand        | 93    |
| 18  | Thailand        | 82    | Slovenia        | 78    | Poland        | 74    | Guam            | 74    | Canada          | 91    |
| 19  | Austria         | 82    | New Zealand     | 76    | France        | 74    | Czechia         | 74    | Israel          | 88    |
| 20  | Saudi Arabia    | 79    | Malaysia        | 76    | Portugal      | 72    | Ireland         | 72    | Luxembourg      | 84    |
| 21  | Luxembourg      | 78    | Saudi Arabia    | 75    | Maldives      | 71    | Maldives        | 71    | New Zealand     | 80    |
| 22  | Maldives        | 76    | Malta           | 74    | United States | 70    | Tonga           | 69    | Malta           | 80    |
| 23  | Brunei Darus.   | 74    | Turkmenistan    | 70    | Guam          | 68    | China           | 69    | Iceland         | 80    |
| 24  | Malta           | 69    | Belgium         | 70    | Slovak Rep.   | 67    | Mexico          | 67    | Germany         | 78    |
| 25  | Slovenia        | 67    | Cyprus          | 68    | Tonga         | 66    | France          | 64    | Malaysia        | 77    |
| 26  | Netherlands     | 67    | China           | 68    | Luxembourg    | 66    | Iceland         | 63    | Mexico          | 74    |
| 27  | Belgium         | 65    | Tonga           | 65    | Finland       | 66    | Malaysia        | 62    | Maldives        | 74    |
| 28  | Canada          | 62    | Maldives        | 64    | China         | 65    | Viet Nam        | 61    | China           | 73    |
| 29  | Czechia         | 61    | Austria         | 60    | Mexico        | 64    | Ecuador         | 61    | Viet Nam        | 67    |
| 30  | Poland          | 60    | Estonia         | 59    | Italy         | 62    | Belgium         | 61    | Turkmenistan    | 67    |
| 31  | Ecuador         | 60    | Russian Fed.    | 57    | Hungary       | 61    | Barbados        | 61    | Puerto Rico     | 67    |
| 32  | China           | 60    | Poland          | 56    | Croatia       | 61    | Portugal        | 59    | Belgium         | 67    |
| 33  | New Zealand     | 59    | Viet Nam        | 55    | Turkmenistan  | 60    | Canada          | 59    | Ecuador         | 64    |
| 34  | Panama          | 58    | Czechia         | 54    | Sweden        | 58    | Peru            | 58    | Australia       | 60    |
| 35  | Mauritius       | 56    | Australia       | 54    | Guatemala     | 58    | Italy           | 58    | El Salvador     | 57    |
| 36  | Cuba            | 56    | United States   | 53    | Bahamas       | 57    | Finland         | 57    | Cambodia        | 57    |
| 37  | Peru            | 54    | Fiji            | 53    | Puerto Rico   | 56    | Denmark         | 55    | Czechia         | 56    |
| 38  | Finland         | 53    | Denmark         | 53    | Malaysia      | 56    | Panama          | 53    | Cyprus          | 55    |
| 39  | Philippines     | 51    | Finland         | 51    | Ecuador       | 56    | Uruguay         | 51    | Indonesia       | 54    |
| 40  | Guam            | 51    | Iceland         | 48    | Cyprus        | 56    | Poland          | 51    | Papua N.Guinea  | 53    |
| 41  | Russian Fed.    | 48    | Croatia         | 48    | Fiji          | 54    | Fiji            | 50    | Panama          | 53    |
| 42  | Portugal        | 48    | Cambodia        | 48    | Latvia        | 53    | Sweden          | 49    | Bolivia         | 53    |
| 43  | Cyprus          | 48    | Solomon Isl.    | 47    | Barbados      | 52    | United Arab Em. | 48    | Finland         | 52    |
| 44  | France          | 46    | Philippines     | 47    | Bahrain       | 52    | Slovak Republic | 48    | Netherlands     | 51    |
| 45  | Solomon Isl.    | 45    | Portugal        | 46    | Panama        | 50    | Guatemala       | 47    | United Kingdom  | 50    |
| 46  | Slovak Republic | 45    | Indonesia       | 46    | Moldova       | 50    | Cyprus          | 47    | Costa Rica      | 50    |
| 47  | Lithuania       | 45    | Guatemala       | 46    | Estonia       | 49    | Cambodia        | 45    | Azerbaijan      | 49    |
| 48  | Ireland         | 45    | Canada          | 45    | Iceland       | 48    | Bahamas. The    | 45    | Barbados        | 48    |
| 49  | Estonia         | 45    | Sweden          | 44    | Viet Nam      | 47    | Philippines     | 44    | Poland          | 46    |
| 50  | Fiji            | 44    | Romania         | 44    | Romania       | 47    | Singapore       | 42    | Russian Fed.    | 45    |

Table 4 presents the results for the top-50 dominating queries for the years 2019 to 2023 for further inspection. It is interesting that there are countries in the top positions that have not appeared on the skyline. Also, we can detect that countries which have appeared on the skyline constantly in all five years do not hold their top positions and there are important changes in the scores. It would be very

interesting to further investigate the economic performance in the results with more specialized methods.

### 3.2 Finding countries with sustainable economic performance and low environmental cost

In the following case study, we want to identify countries that achieve high GDP with low environmental degradation measured by carbon emissions. Skyline and top- $k$  dominating queries will return a list of countries that are experiencing good economic performance, while minimizing their environmental impact. These countries represent a "green growth" model.

A summary of the applied criteria / dimensions follows:

- *GDP (higher values are better)*. For this factor we used the "GDP (current US\$)" from World Development Indicators Data Bank, which is the GDP in current US\$. As higher the GDP is, the more production power the country has.
- *Carbon emissions (lower values are better)*. For this factor we used the "Carbon dioxide (CO<sub>2</sub>) emissions excluding LULUCF per capita (t CO<sub>2</sub>e/capita)" from World Development Indicators Data Bank, which is the total annual emissions of carbon dioxide (CO<sub>2</sub>), one of the six Kyoto greenhouse gases (GHG), from the agriculture, energy, waste, and industrial sectors, excluding LULUCF, standardized to carbon dioxide equivalent values divided by the economy's population. This measure excludes GHG fluxes caused by Land Use Change Land Use and Forestry (LULUCF), as these fluxes have larger uncertainties.

Table 5 presents the results for the skyline queries in alphabetical order for the years 2019 to 2023. It is interesting that some countries like China, Congo, Ethiopia, Germany, India, Marshall Islands, Micronesia, Nauru, Nigeria, Tuvalu, United States are constantly reported as skyline countries in all five years. Moreover, there are some countries that are reported in the results but only for some years like Guam, Japan, United Kingdom, Virgin Islands.

Table 5: Results of skyline queries for GDP and carbon emissions

|      |                                                                                                                                                                                        |
|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2019 | China, Congo. Dem. Rep., Ethiopia, Germany, Guam, India, Kenya, Marshall Islands, Micronesia. Fed. Sts., Nauru, Nigeria, Tuvalu, United Kingdom, United States, Virgin Islands (U.S.). |
| 2020 | China, Congo. Dem. Rep., Ethiopia, Germany, Guam, India, Japan, Marshall Islands, Micronesia. Fed. Sts., Nauru, Nigeria, Tuvalu, United Kingdom, United States, Virgin Islands (U.S.). |
| 2021 | China, Congo. Dem. Rep., Ethiopia, Germany, Guam, India, Japan, Marshall Islands, Micronesia. Fed. Sts., Nauru, Nigeria, Tuvalu, United States, Virgin Islands (U.S.).                 |
| 2022 | China, Congo. Dem. Rep., Ethiopia, Germany, Guam, India, Japan, Marshall Islands, Micronesia. Fed. Sts., Nauru, Nigeria, Tuvalu, United States, Virgin Islands (U.S.).                 |
| 2023 | Bangladesh, China, Congo. Dem. Rep., Ethiopia, Germany, India, Marshall Islands, Micronesia. Fed. Sts., Nauru, Nigeria, Tuvalu, United States.                                         |

Table 6 presents the results for the top-50 dominating queries for the years 2019 to 2023 for further inspection. It is interesting that the results appear to be more constant over the years, as most countries hold their top positions. However, there are some countries in the top positions that have not appeared on the skyline. It would be very interesting to further investigate the economic performance with respect to environmental cost in the results with more specialized methods.

Table 6: Results of top-50 domination queries for GDP and carbon emissions

| Top | 2019             |       | 2020           |       | 2021           |       | 2022           |       | 2023           |       |
|-----|------------------|-------|----------------|-------|----------------|-------|----------------|-------|----------------|-------|
|     | Country          | Score | Country        | Score | Country        | Score | Country        | Score | Country        | Score |
| 1   | Nigeria          | 137   | Nigeria        | 134   | Nigeria        | 129   | Ethiopia       | 131   | Ethiopia       | 132   |
| 2   | Ethiopia         | 123   | Ethiopia       | 128   | Ethiopia       | 128   | Nigeria        | 129   | Nigeria        | 122   |
| 3   | Bangladesh       | 122   | Bangladesh     | 128   | Bangladesh     | 122   | Bangladesh     | 120   | Bangladesh     | 121   |
| 4   | India            | 116   | India          | 117   | India          | 119   | India          | 116   | India          | 113   |
| 5   | Congo. Dem. R.   | 112   | Congo. Dem. R. | 114   | Congo. Dem. R. | 114   | Congo. Dem. R. | 115   | Congo. Dem. R. | 112   |
| 6   | Pakistan         | 108   | Kenya          | 109   | Kenya          | 109   | Pakistan       | 108   | Pakistan       | 108   |
| 7   | Kenya            | 108   | Pakistan       | 107   | Tanzania       | 104   | Kenya          | 107   | Sudan          | 104   |
| 8   | Brazil           | 104   | Tanzania       | 104   | Pakistan       | 103   | Tanzania       | 105   | Brazil         | 104   |
| 9   | Tanzania         | 99    | Philippines    | 103   | Uganda         | 98    | Brazil         | 101   | Kenya          | 103   |
| 10  | Philippines      | 99    | Brazil         | 99    | Philippines    | 98    | Uganda         | 99    | Philippines    | 100   |
| 11  | Indonesia        | 97    | Uganda         | 97    | Indonesia      | 97    | Philippines    | 96    | Uganda         | 99    |
| 12  | Uganda           | 92    | Indonesia      | 95    | Cote d'Ivoire  | 95    | Indonesia      | 94    | Tanzania       | 99    |
| 13  | Myanmar          | 92    | Cote d'Ivoire  | 95    | Brazil         | 95    | Cote d'Ivoire  | 89    | Indonesia      | 96    |
| 14  | Colombia         | 91    | Myanmar        | 93    | Colombia       | 88    | Angola         | 89    | Cote d'Ivoire  | 90    |
| 15  | Ghana            | 88    | Colombia       | 88    | Myanmar        | 85    | Colombia       | 87    | Colombia       | 85    |
| 16  | Cote d'Ivoire    | 88    | Egypt. Arab R. | 85    | Ghana          | 85    | Egypt. Arab R. | 85    | Cameroon       | 85    |
| 17  | Angola           | 83    | Ghana          | 84    | Cameroon       | 85    | Sudan          | 84    | Angola         | 84    |
| 18  | Sri Lanka        | 80    | Peru           | 82    | Peru           | 82    | Ghana          | 83    | Peru           | 82    |
| 19  | Peru             | 80    | Cameroon       | 82    | Egypt. Arab R. | 82    | Myanmar        | 81    | Myanmar        | 80    |
| 20  | Cameroon         | 79    | Sri Lanka      | 80    | Sri Lanka      | 81    | Cameroon       | 81    | Ghana          | 80    |
| 21  | Egypt. Arab Rep. | 78    | Angola         | 79    | Angola         | 80    | Peru           | 80    | Egypt. Arab R. | 79    |
| 22  | Guatemala        | 77    | Mexico         | 77    | Guatemala      | 77    | Sri Lanka      | 79    | Sri Lanka      | 77    |
| 23  | Nepal            | 75    | Guatemala      | 77    | Mexico         | 76    | Guatemala      | 78    | Guatemala      | 76    |
| 24  | Afghanistan      | 75    | Afghanistan    | 77    | Sudan          | 74    | Mexico         | 74    | Mexico         | 74    |
| 25  | Mexico           | 73    | Sudan          | 72    | Nepal          | 72    | Nepal          | 73    | Sweden         | 72    |
| 26  | Sudan            | 71    | Nepal          | 72    | Burkina Faso   | 71    | Morocco        | 71    | Morocco        | 72    |
| 27  | Morocco          | 68    | Morocco        | 71    | Niger          | 69    | Guinea         | 69    | Guinea         | 71    |
| 28  | Sweden           | 66    | Burkina Faso   | 71    | Haiti          | 69    | Zambia         | 68    | Nepal          | 70    |
| 29  | Zambia           | 65    | Zimbabwe       | 68    | Morocco        | 68    | Pap. N. Guinea | 68    | France         | 70    |
| 30  | Thailand         | 65    | Sweden         | 68    | Mali           | 67    | Zimbabwe       | 67    | Burkina Faso   | 67    |
| 31  | Mali             | 64    | Niger          | 67    | Sweden         | 66    | Sweden         | 66    | Zimbabwe       | 66    |
| 32  | Burkina Faso     | 64    | Mali           | 67    | Zambia         | 65    | Switzerland    | 65    | Zambia         | 66    |
| 33  | Costa Rica       | 63    | Cuba           | 66    | Thailand       | 65    | Haiti          | 65    | Switzerland    | 66    |
| 34  | Argentina        | 63    | Madagascar     | 65    | Pap. N. Guinea | 65    | Viet Nam       | 64    | Niger          | 66    |
| 35  | Zimbabwe         | 62    | Senegal        | 64    | Zimbabwe       | 64    | Niger          | 63    | Mozambique     | 66    |
| 36  | France           | 62    | Pap. N. Guinea | 64    | Madagascar     | 63    | Burkina Faso   | 63    | Mali           | 66    |
| 37  | Ecuador          | 62    | France         | 64    | Guinea         | 63    | France         | 62    | Costa Rica     | 65    |
| 38  | Madagascar       | 61    | Costa Rica     | 64    | Senegal        | 62    | Senegal        | 61    | Un. Kingdom    | 64    |
| 39  | Cuba             | 61    | Zambia         | 63    | Mozambique     | 61    | Madagascar     | 61    | Senegal        | 63    |
| 40  | Cambodia         | 61    | Thailand       | 61    | France         | 60    | Cambodia       | 60    | Pap. N. Guinea | 63    |
| 41  | Switzerland      | 60    | Mozambique     | 61    | Ecuador        | 60    | Mozambique     | 59    | Haiti          | 63    |
| 42  | Senegal          | 60    | Ecuador        | 61    | Costa Rica     | 60    | Mali           | 59    | Thailand       | 62    |
| 43  | Pap. N. Guinea   | 60    | Argentina      | 61    | Afghanistan    | 60    | Ecuador        | 59    | Madagascar     | 61    |
| 44  | Viet Nam         | 59    | Viet Nam       | 59    | Cambodia       | 59    | Costa Rica     | 59    | Argentina      | 61    |
| 45  | Niger            | 59    | Guinea         | 59    | Viet Nam       | 57    | Thailand       | 58    | Afghanistan    | 61    |
| 46  | Mozambique       | 59    | Un. Kingdom    | 58    | Un. Kingdom    | 57    | Un. Kingdom    | 57    | Cambodia       | 60    |
| 47  | Haiti            | 57    | Switzerland    | 58    | Honduras       | 57    | Honduras       | 57    | Benin          | 59    |
| 48  | United Kingdom   | 55    | Haiti          | 58    | Benin          | 56    | Rwanda         | 56    | Honduras       | 58    |
| 49  | Dominican Rep.   | 55    | Cambodia       | 58    | Switzerland    | 55    | Paraguay       | 56    | Viet Nam       | 57    |
| 50  | Uruguay          | 54    | Honduras       | 56    | Paraguay       | 55    | Argentina      | 56    | Spain          | 57    |

### 3.3 Finding countries with sustainable economic growth and low income inequality

In the following case study, we want to identify countries that achieve high GDP growth, while keeping income inequality low (measured by the Gini index). Skyline and top- $k$  dominating queries will return a list of countries that achieve this balance and often provide both high economic output and more equitable income distribution, which is considered an ideal model for sustainable economic development.

A summary of the applied criteria / dimensions follows:

- *GDP growth rate (higher values are better)*. For this factor we used the “GDP growth (annual %)” from World Development Indicators Data Bank, which is the annual percentage growth rate of GDP at market prices based on constant local currency. Aggregates are based on constant 2015 prices, expressed in U.S. dollars.
- *Gini index (lower values are better, indicating less inequality)*. For this factor we used the “Gini index” from World Development Indicators Data Bank. The Gini index measures the extent to which the distribution of income or consumption among individuals or households within an economy deviates from a perfectly equal distribution. A Gini index of 0 represents perfect equality, while an index of 100 implies perfect inequality.

Table 7 presents the results for the skyline queries in alphabetical order for the years 2019 to 2023. It is interesting that in this case there are no countries that are constantly reported as skyline countries in all five years. Moreover, there are few countries in the results and there are important changes from year to year.

Table 7: Results of skyline queries for GDP growth rate and Gini index

|      |                                                                                                                                            |
|------|--------------------------------------------------------------------------------------------------------------------------------------------|
| 2019 | Armenia, Czechia, Kazakhstan, Maldives, Marshall Islands, Poland, Slovak Republic, Slovenia, Timor-Leste, Tuvalu.                          |
| 2020 | Belarus, Guyana, Ireland, Slovak Republic, Slovenia, Timor-Leste.                                                                          |
| 2021 | Aruba, Belize, Guyana, Ireland, Libya, Maldives, Moldova, Monaco, Panama, Slovak Republic, Slovenia.                                       |
| 2022 | Armenia, Barbados, Cabo Verde, Fiji, Guyana, Kyrgyz Republic, Maldives, Seychelles, St. Lucia.                                             |
| 2023 | Armenia, Congo. Dem. Rep., Costa Rica, Fiji, Georgia, Guyana, India, Indonesia, Libya, Malta, Mongolia, Panama, Rwanda, Samoa, Tajikistan. |

Table 8 presents the results for the top-50 dominating queries for the years 2019 to 2023 for further inspection. It is interesting that there are some countries in the top positions that have not appeared on the skyline. Furthermore, we can detect that there are important changes in the scores from year to year. Moreover, we can see that less results are provided for the years 2022 and 2023, due to the existence of missing data in the Gini index. In (Tiakas et al, 2024) the authors present several approaches for handling missing data. For the applied skyline and top-50 domination queries in this case study, we did not include the specific domination checks for the countries with missing data. In addition, we did not present countries with a zero-dominance score in Table 8. It would be very interesting to further investigate the economic growth with respect to income inequality in the results with more specialized methods.

Table 8: Results of top-50 domination queries for GDP growth rate and Gini index

|     | 2019             |       | 2020             |       | 2021            |       | 2022               |       | 2023       |       |
|-----|------------------|-------|------------------|-------|-----------------|-------|--------------------|-------|------------|-------|
| Top | Country          | Score | Country          | Score | Country         | Score | Country            | Score | Country    | Score |
| 1   | Maldives         | 177   | Ireland          | 188   | Moldova         | 192   | Armenia            | 195   | Panama     | 189   |
| 2   | Armenia          | 177   | Belarus          | 158   | Ireland         | 181   | Georgia            | 187   | Costa Rica | 164   |
| 3   | Marshall Islands | 153   | Iran. Islamic R. | 152   | Croatia         | 180   | Kyrgyz Republic    | 185   | Indonesia  | 162   |
| 4   | Cyprus           | 152   | Viet Nam         | 148   | Cyprus          | 169   | Viet Nam           | 170   | Ecuador    | 89    |
| 5   | Egypt. Arab Rep. | 144   | China            | 146   | Slovenia        | 162   | Bangladesh         | 162   |            |       |
| 6   | Hungary          | 137   | Korea. Rep.      | 135   | Montenegro      | 160   | Uzbekistan         | 148   |            |       |
| 7   | Ireland          | 136   | Denmark          | 135   | India           | 155   | Colombia           | 147   |            |       |
| 8   | Poland           | 135   | Turkiye          | 133   | Georgia         | 151   | Nepal              | 143   |            |       |
| 9   | Kazakhstan       | 134   | Luxembourg       | 133   | United Kingdom  | 150   | Ecuador            | 136   |            |       |
| 10  | Kyrgyz Republic  | 132   | Poland           | 129   | Greece          | 147   | Indonesia          | 133   |            |       |
| 11  | China            | 128   | Sweden           | 128   | Denmark         | 145   | Bhutan             | 131   |            |       |
| 12  | Uganda           | 122   | Gambia. The      | 128   | Dominican Rep.  | 143   | Mongolia           | 126   |            |       |
| 13  | Malawi           | 122   | Slovak Republic  | 127   | Peru            | 140   | Argentina          | 125   |            |       |
| 14  | Slovenia         | 121   | Lithuania        | 127   | Italy           | 139   | Dominican Rep.     | 122   |            |       |
| 15  | Czechia          | 121   | Congo. Dem. R.   | 127   | El Salvador     | 139   | Zambia             | 117   |            |       |
| 16  | Moldova          | 120   | Burundi          | 127   | Serbia          | 138   | Uruguay            | 112   |            |       |
| 17  | Malta            | 120   | Kenya            | 124   | Hungary         | 136   | Costa Rica         | 102   |            |       |
| 18  | Georgia          | 116   | Serbia           | 123   | Luxembourg      | 135   | Iran. Islamic Rep. | 89    |            |       |
| 19  | Ukraine          | 115   | Finland          | 123   | Estonia         | 134   | Mexico             | 79    |            |       |
| 20  | Serbia           | 114   | Kazakhstan       | 122   | Poland          | 133   | Chad               | 68    |            |       |
| 21  | Indonesia        | 114   | Switzerland      | 113   | Netherlands     | 132   | El Salvador        | 67    |            |       |
| 22  | Kiribati         | 113   | Paraguay         | 113   | Panama          | 130   | Brazil             | 65    |            |       |
| 23  | Lithuania        | 110   | Israel           | 112   | Israel          | 130   | Peru               | 62    |            |       |
| 24  | Estonia          | 108   | Estonia          | 111   | China           | 130   | United States      | 51    |            |       |
| 25  | Croatia          | 106   | Russian Fed.     | 109   | Belgium         | 129   | Suriname           | 50    |            |       |
| 26  | North Maced.     | 103   | Indonesia        | 106   | Turkiye         | 127   | Chile              | 47    |            |       |
| 27  | Dominican Rep.   | 103   | Albania          | 106   | France          | 127   | Syrian Arab Rep.   | 30    |            |       |
| 28  | India            | 102   | Cyprus           | 103   | Benin           | 127   | Paraguay           | 26    |            |       |
| 29  | Vanuatu          | 101   | United States    | 102   | Argentina       | 125   |                    |       |            |       |
| 30  | Romania          | 100   | Ukraine          | 99    | Latvia          | 124   |                    |       |            |       |
| 31  | Mauritania       | 100   | Slovenia         | 98    | Cote d'Ivoire   | 123   |                    |       |            |       |
| 32  | Montenegro       | 99    | Netherlands      | 97    | Spain           | 121   |                    |       |            |       |
| 33  | Belgium          | 92    | Malta            | 97    | Ecuador         | 121   |                    |       |            |       |
| 34  | Sweden           | 91    | Germany          | 89    | Colombia        | 121   |                    |       |            |       |
| 35  | Luxembourg       | 90    | Bulgaria         | 89    | Slovak Republic | 119   |                    |       |            |       |
| 36  | Israel           | 90    | Romania          | 87    | Kenya           | 118   |                    |       |            |       |
| 37  | Bulgaria         | 88    | Latvia           | 86    | Bulgaria        | 118   |                    |       |            |       |
| 38  | Slovak Republic  | 87    | Hungary          | 86    | Guinea-Bissau   | 117   |                    |       |            |       |
| 39  | Portugal         | 87    | Belgium          | 85    | Armenia         | 117   |                    |       |            |       |
| 40  | Netherlands      | 84    | Brazil           | 82    | Sweden          | 116   |                    |       |            |       |
| 41  | Greece           | 76    | Czechia          | 78    | Burkina Faso    | 115   |                    |       |            |       |
| 42  | Panama           | 75    | Costa Rica       | 69    | Senegal         | 114   |                    |       |            |       |
| 43  | Korea. Rep.      | 74    | India            | 68    | Lithuania       | 112   |                    |       |            |       |
| 44  | Albania          | 74    | Austria          | 64    | Costa Rica      | 109   |                    |       |            |       |
| 45  | Colombia         | 73    | Thailand         | 62    | Kyrgyz Republic | 107   |                    |       |            |       |
| 46  | United States    | 72    | Georgia          | 61    | United States   | 106   |                    |       |            |       |
| 47  | France           | 70    | Kyrgyz Republic  | 60    | Togo            | 105   |                    |       |            |       |
| 48  | El Salvador      | 70    | Armenia          | 58    | Russian Fed.    | 103   |                    |       |            |       |
| 49  | Canada           | 66    | Dominican Rep.   | 56    | Romania         | 102   |                    |       |            |       |
| 50  | Russian Fed.     | 65    | France           | 55    | Portugal        | 102   |                    |       |            |       |

### 3.4 Finding countries with optimal performance in all criteria studied

In this case study we want to identify countries that outperform their peers in all criteria studied, i.e., GDP, GDP per capita, GDP growth rate, unemployment rate, inflation rate, carbon emissions, and Gini index. As we increase the dimensionality, we expect that skyline queries will return more results and top- $k$  dominating queries will provide much less scores due to the important reduce of existing dominations. We keep in mind that the eliminating dimension is  $d_0 \approx 2[\ln N] + 2$ , and as we have  $N=205$  countries, we derive that  $d_0 \approx 14$  dimensions. Therefore, if we had 14 or more dimensions / criteria, almost all dominance scores would become zero, and almost all countries would be included in the skyline. However, even with the 7 dimensions of this case study, we can validate an important reduction in dominations between the countries.

Table 9 presents the results for the skyline queries. Indeed, a large number of countries were reported in the results, thus we did not include their names. Therefore, this time the skyline queries did not return informative results.

*Table 9: Results of skyline queries for all criteria studied*

|      |                         |
|------|-------------------------|
| 2019 | 152 countries reported. |
| 2020 | 146 countries reported. |
| 2021 | 139 countries reported. |
| 2022 | 140 countries reported. |
| 2023 | 140 countries reported. |

Table 10 presents the results for the top-50 dominating queries for the years 2019 to 2023 for further inspection. We can clearly see that the domination scores have been reduced significantly, which proves that there is an important reduction in the number of dominations between the countries. However, it is interesting that there are countries in the top results that also appeared in high positions in the sub-dimensional results. It would be very interesting to further investigate the results with more specialized methods.

## 4. Conclusions

In this paper we applied the skyline and top- $k$  dominating queries in interesting problems and contexts involving economic, sustainability and environmental data. For this application we selected the challenging problem of country ranking, as it has several difficulties. Only explicit and specialized methods have been proposed, and we obtained interesting results. However, skyline and top- $k$  dominating queries can be applied to many other multi-criteria problems, without limitations for the selection of the criteria, and without the need for transforming, combining, or making any calculation on the corresponding raw data. Moreover, we discussed the advantages and disadvantages of skyline and top- $k$  dominating queries, which we validated in the results. An important conclusion in the proposed methodology, in case that we have many criteria or dimensions, is that we can reach much more informative results if we split them into subgroups with a specific meaning and then apply the skyline and top- $k$  dominating queries in those subgroups. Another conclusion is that we must not reach the eliminating dimension, as we will take trivial results.

Table 10: Results of top-50 domination queries for all criteria studied

|     | 2019           |       | 2020           |       | 2021           |       | 2022          |       | 2023                |       |
|-----|----------------|-------|----------------|-------|----------------|-------|---------------|-------|---------------------|-------|
| Top | Country        | Score | Country        | Score | Country        | Score | Country       | Score | Country             | Score |
| 1   | Sweden         | 13    | Switzerland    | 16    | Un. Kingdom    | 16    | Un. Kingdom   | 14    | Cote d'Ivoire       | 15    |
| 2   | Switzerland    | 10    | Ireland        | 14    | Ireland        | 14    | Israel        | 14    | Niger               | 13    |
| 3   | Guam           | 10    | Cote d'Ivoire  | 11    | Malta          | 13    | Switzerland   | 11    | Chad                | 13    |
| 4   | France         | 10    | Uganda         | 10    | Israel         | 12    | Portugal      | 11    | Uganda              | 12    |
| 5   | Cote d'Ivoire  | 9     | Sweden         | 10    | Sweden         | 11    | Netherlands   | 11    | Switzerland         | 12    |
| 6   | Virgin Islands | 8     | Bangladesh     | 9     | Netherlands    | 11    | Panama        | 10    | Malta               | 11    |
| 7   | Uganda         | 8     | Tanzania       | 8     | Denmark        | 11    | Ireland       | 10    | Denmark             | 11    |
| 8   | Bangladesh     | 8     | Norway         | 8     | Switzerland    | 10    | Guam          | 9     | Costa Rica          | 11    |
| 9   | Un. Kingdom    | 7     | Kenya          | 8     | Portugal       | 10    | Uruguay       | 8     | Cambodia            | 11    |
| 10  | Kenya          | 7     | Israel         | 8     | Peru           | 10    | Uganda        | 8     | Burundi             | 11    |
| 11  | Israel         | 7     | Singapore      | 7     | Panama         | 9     | Niger         | 8     | Togo                | 10    |
| 12  | Denmark        | 7     | Niger          | 7     | Guatemala      | 9     | Italy         | 8     | Solomon Islands     | 10    |
| 13  | Austria        | 7     | Slovenia       | 6     | Ecuador        | 9     | Austria       | 8     | Philippines         | 10    |
| 14  | Thailand       | 6     | Qatar          | 6     | Cote d'Ivoire  | 9     | Tanzania      | 7     | Panama              | 10    |
| 15  | Puerto Rico    | 6     | Oman           | 6     | Uganda         | 8     | New Zealand   | 7     | Guinea-Bissau       | 10    |
| 16  | Peru           | 6     | Malta          | 6     | Slovenia       | 8     | Mexico        | 7     | Benin               | 10    |
| 17  | Pap. N. Guinea | 6     | Japan          | 6     | Mexico         | 8     | Dominican R.  | 7     | Timor-Leste         | 9     |
| 18  | Panama         | 6     | Guatemala      | 6     | Italy          | 8     | Croatia       | 7     | Tanzania            | 9     |
| 19  | Italy          | 6     | Guam           | 6     | France         | 8     | Costa Rica    | 7     | Papua New Guinea    | 9     |
| 20  | Guatemala      | 6     | Ethiopia       | 6     | Croatia        | 8     | Barbados      | 7     | Madagascar          | 9     |
| 21  | Cyprus         | 6     | Cyprus         | 6     | Tanzania       | 7     | Puerto Rico   | 6     | Guatemala           | 9     |
| 22  | United States  | 5     | Chad           | 6     | Kenya          | 7     | Peru          | 6     | Congo. Dem. Rep.    | 9     |
| 23  | Tanzania       | 5     | Un. Arab Em.   | 5     | Japan          | 7     | Malaysia      | 6     | Sierra Leone        | 8     |
| 24  | Portugal       | 5     | Saudi Arabia   | 5     | Guam           | 7     | Germany       | 6     | Senegal             | 8     |
| 25  | Nigeria        | 5     | Portugal       | 5     | Cyprus         | 7     | Ecuador       | 6     | Nigeria             | 8     |
| 26  | Malta          | 5     | Latvia         | 5     | Bangladesh     | 7     | Cote d'Ivoire | 6     | Mali                | 8     |
| 27  | Luxembourg     | 5     | Kuwait         | 5     | Niger          | 6     | Bangladesh    | 6     | Israel              | 8     |
| 28  | Ireland        | 5     | Indonesia      | 5     | New Zealand    | 6     | Togo          | 5     | Ethiopia            | 8     |
| 29  | Indonesia      | 5     | Guinea-Bissau  | 5     | Latvia         | 6     | Pap.N. Guinea | 5     | Cuba                | 8     |
| 30  | Guinea-Bissau  | 5     | Guinea         | 5     | Ethiopia       | 6     | Guinea-Bissau | 5     | Brazil              | 8     |
| 31  | Ethiopia       | 5     | Estonia        | 5     | El Salvador    | 6     | Guinea        | 5     | Bangladesh          | 8     |
| 32  | Congo. D. Rep. | 5     | El Salvador    | 5     | Dominican R.   | 6     | Greece        | 5     | Vanuatu             | 7     |
| 33  | Chad           | 5     | Ecuador        | 5     | Belgium        | 6     | Denmark       | 5     | Tonga               | 7     |
| 34  | Cameroon       | 5     | Cuba           | 5     | Bahamas. The   | 6     | Cyprus        | 5     | Paraguay            | 7     |
| 35  | Un. Arab Em.   | 4     | Costa Rica     | 5     | Austria        | 6     | Congo. D. R.  | 5     | Myanmar             | 7     |
| 36  | Togo           | 4     | Canada         | 5     | United States  | 5     | Colombia      | 5     | Mozambique          | 7     |
| 37  | Spain          | 4     | Cameroon       | 5     | Togo           | 5     | Chad          | 5     | Mexico              | 7     |
| 38  | Slovak Rep.    | 4     | Virgin Islands | 4     | Slovak Rep.    | 5     | Cambodia      | 5     | Liberia             | 7     |
| 39  | Sierra Leone   | 4     | United States  | 4     | Korea. Rep.    | 5     | Brazil        | 5     | Indonesia           | 7     |
| 40  | Philippines    | 4     | Togo           | 4     | Greece         | 5     | Belgium       | 5     | Guinea              | 7     |
| 41  | Niger          | 4     | Thailand       | 4     | Germany        | 5     | Bahamas. The  | 5     | Guam                | 7     |
| 42  | Myanmar        | 4     | Sierra Leone   | 4     | Finland        | 5     | Australia     | 5     | Ghana               | 7     |
| 43  | Madagascar     | 4     | Puerto Rico    | 4     | Chad           | 5     | United States | 4     | Cameroon            | 7     |
| 44  | Lithuania      | 4     | Philippines    | 4     | Cambodia       | 5     | Spain         | 4     | Burkina Faso        | 7     |
| 45  | Ghana          | 4     | Peru           | 4     | Burundi        | 5     | Solomon Isl.  | 4     | Pakistan            | 6     |
| 46  | Finland        | 4     | Paraguay       | 4     | Burkina Faso   | 5     | Slovenia      | 4     | Nicaragua           | 6     |
| 47  | El Salvador    | 4     | Pap. N. Guinea | 4     | Benin          | 5     | Singapore     | 4     | Malawi              | 6     |
| 48  | Cuba           | 4     | Nigeria        | 4     | Virgin Islands | 4     | Sierra Leone  | 4     | Korea. Dem. P. Rep. | 6     |
| 49  | Croatia        | 4     | New Zealand    | 4     | Sri Lanka      | 4     | Madagascar    | 4     | Guyana              | 6     |
| 50  | Costa Rica     | 4     | Lithuania      | 4     | Spain          | 4     | Japan         | 4     | Gambia. The         | 6     |

An interesting future work will be to use the rankings, the scores and the indicators of the specialized proposed methods for country ranking, as separate criteria / dimensions, possibly combining them with other default indicators, and applying the skyline and top- $k$  domination queries. Another direction for future work is to apply skyline and top- $k$  domination queries in the performance / ranking / rating problem of banks or organizations, or any other interesting problem.

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# **A CRM system for sustainable agriculture to support customized spraying programs using drones**

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## **Abstract**

Precision agriculture and in particular the replacement of conventional pesticide spraying methods with aerial spraying using Unmanned Aerial Vehicles -UAVs (drones) is highly promising towards sustainability goals. Challenges in this field are the effective management of individual farmers' customized needs, as well as the integration of information that would allow optimized spraying programs. In this paper, we surveyed the functional requirements and information management needs of a specialized Customer Relationship Management (CRM) system addressed to agricultural spraying companies. The aim of the proposed system was to effectively manage information about characteristics and special requirements of individual farms, pesticide spraying history and information on crops' health, and to integrate them with efficiency metrics and environmental performance indicators. The end goal was to design an integrated information system to facilitate intelligent decision support for spraying program customization and thus contribute towards sustainability. Initially, we performed a review of sustainability strategies, policies and indicators linked to precision agriculture and a literature survey on the use of drones for efficient pesticide spraying. Observational research was then carried out to identify the characteristics and functionality offered by existing commercial Agriculture Information Systems (AIS), Farm Management Information Systems (FMIS), precision agriculture research platforms, as well as specialized software for managing drone spraying flights. Additionally, an experiment was carried out in collaboration with an agricultural drone company, where the water and energy consumption indicators of a commercial drone model were recorded in real conditions and compared with the corresponding measures of ground pesticide spraying processes. Based on these results and a primary qualitative survey with the owner of the agriculture drone company, the architecture, functional requirements and information model were configured for a proposed CRM, suitable for customized drone spraying optimization.

**Keywords:** *CRM, sustainable agriculture, drones, pesticide spraying customization, sustainability indicators in agriculture*

## **1. Introduction**

The agricultural industry is facing new challenges that mainly concern its urgent need for transformation. Nowadays, farmers, scientists and stakeholders in the agricultural sector are focusing on transitioning from traditional practices to what is known as precision agriculture. The development of new technologies has a direct impact on agricultural methods creating an international trend towards precision agriculture and Agriculture 4.0. This is a new farm management approach in which the use of resources and the agricultural practices are adjusted in ways that increase crop yield and

quality, ensure the proper use of agrochemicals, conserve energy, and protect the environment. This transition also feeds into the Fourth Agricultural Revolution, commonly referred to as Agriculture 4.0, which essentially promotes the integration of digital technologies to transform agriculture into a smart, efficient, and environmentally responsible sector on a global scale (Javaid M. et al., 2022).

Water is a vital public resource essential for humanity. According to the Food and Agriculture Organization (FAO) of the United Nations, agriculture is the largest global consumer of water, accounting for 70% of total water withdrawals. This highlights the strong connection between agriculture and water usage, especially for irrigation. As a result, global organizations like the FAO actively support better management of water resources, helping countries adopt techniques to reduce excessive water consumption. At the same time, agriculture also consumes significant amounts of energy. The agri-food sector currently represents 30% of global energy consumption and is linked to greenhouse gas emissions, particularly CO<sub>2</sub>. This underlines the urgent need to reduce agricultural energy consumption by adopting sustainable practices, such as using energy-efficient machinery powered by biofuels or electricity.

Among the multitude of new technologies, which have been developed to increase the efficiency of agricultural practices, it is worth mentioning the use of Unmanned Aerial Vehicles -UAVs (drones), as well as the intelligent information systems for optimizing processes and decision support. Several studies highlight the benefits of using drones in agriculture for tasks like spraying, fertilization, irrigation, disease management, and seed planting (Pathak H. et al., 2020). Pesticide spraying using drones, in particular, is one of the rapidly evolving technologies in precision agriculture, which is highly promising towards sustainability goals. It minimizes farmers' direct exposure to plant protection products, especially in hard-to-reach areas. Additionally, drones allow for precise scheduling, automated operations, and accurate route planning, reducing human error and covering large areas quickly. This can drastically reduce water and energy consumption and at the same time minimize the quantity of pesticides released and protect the farmers' exposure to harmful chemicals, increasing spraying efficiency by up to five times compared to traditional agricultural machinery.

Challenges that remain open for the potential benefits of aerial spraying with drones to be maximized and for such technologies to be widely adopted, are the effective management of individual farmers' customized needs, as well as the integration of information that would allow optimized spraying programs.

In this paper, we surveyed the functional requirements and information management needs of a specialized Customer Relationship Management (CRM) system addressed to agricultural spraying companies. The aim of the proposed system was to manage characteristics and special requirements of individual farms, pesticide spraying history and information on crops' health, and to integrate them with efficiency metrics and environmental performance indicators. The end goal was to design an integrated information system to facilitate intelligent decision support for spraying program customization and thus contribute to sustainable agriculture.

## **2. Research aims and methodology**

The general aim of the current research was to support efficient pesticide spraying using drones, promoting sustainable precision agriculture. In particular, we focused on the designing of a specialized Customer Relationship Management (CRM) system, addressed to agricultural spraying companies, to facilitate information management and intelligent decision support for optimizing custom spraying programs. Specific research aims were:

1. To capture the landscape of existing information systems in precision agriculture and in particular the ones related to aerial spraying with drones.

2. To investigate the functional and informational needs of the envisaged CRM.
3. To evaluate in practice the benefits of replacing conventional machinery with drones and verify the suitability of the proposed system towards sustainability.
4. To propose the architectural design of a novel CRM to support optimal customized processes.

The methodology to address the above aims, as shown in Figure 1, included the following steps:

A literature review of recent research was performed in the field of precision agriculture and more specifically in the use of drones for optimal pesticide spraying. The search for relevant papers started through Google scholar, using the terms «precision agriculture», «modules», «spraying drones», «agriculture information systems», «artificial intelligence», «machine learning», and «IoT». From the results of the search engine, 15 papers were selected as the most useful and additional relevant papers were spotted from their references. Additionally, information sources were searched regarding the contribution of precision spraying to sustainable agriculture, related indicators and statistical data, as well as regulations and reports.

In the next step, observational research was carried out to identify the state of the art in existing commercial Information Systems specialized in precision agriculture and in managing drone spraying flights. Related software was identified using the Google search engine using the keywords «agriculture», «information systems», «precision», «spraying», «drone», «software» and «CRM». Among a long list of findings, we selected the ones relevant to precision spraying with drones, with the additional prerequisite that they can be applied for the purposes of this research, i.e. to support customized spraying programs to enhance sustainability. The study of existing systems focused on identifying their abilities and important design elements, such as architecture, characteristics, offered functionality and parametrization.

In parallel, a qualitative primary survey was carried out through an interview with representatives of a company which owns a fleet of drones and is active in agricultural spraying. The company was interested in adopting the proposed system, was aware of the related requirements, operational demands and potential issues in the field, and was therefore a valuable source for the user requirements analysis.

Finally, an experiment was carried out in collaboration with the above agricultural drone company, where the water and energy consumption indicators of a commercial drone model were recorded in real conditions and compared with the corresponding measures of ground pesticide spraying processes. The purpose of the experiment was to verify in practice the benefits of replacing conventional processes with customized drone spraying, and additionally, through direct involvement in the process, to get a glimpse of the real-life needs of the proposed CRM.

Consolidating the results of the above secondary and primary research, we concluded to a conceptual design and the user requirements for a specialized CRM to facilitate intelligent decision support for spraying program customization. The proposed system aims at effectively managing detailed information about individual farms, pesticide spraying history and information on crops' health, and to integrate them with efficiency metrics and environmental performance indicators.

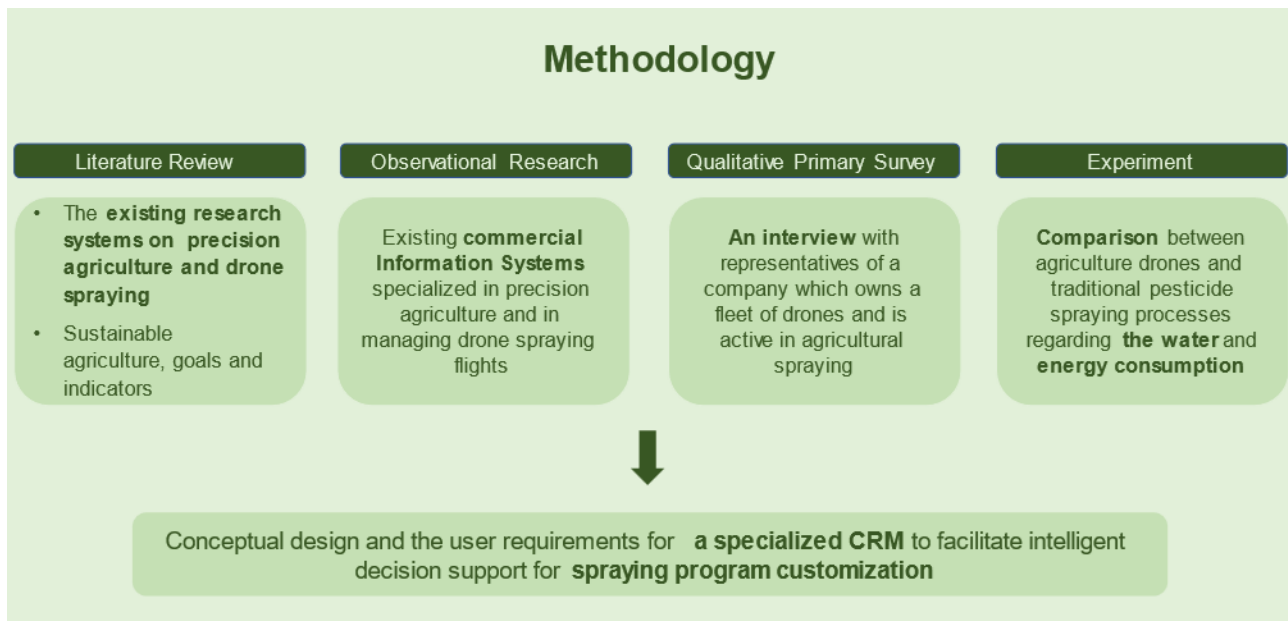


**Figure 1.** *The research methodology.*

### 3. Secondary research

#### 3.1 Background in sustainability issues in agriculture

One of the major goals of Agriculture 4.0 is sustainability in agriculture, which has become a critical global concern, as farming practices directly affect environmental, economic, and social systems. Driven by the need for environmental responsibility, agriculture businesses are thus undergoing sustainable transformation. This new approach, known as ESG (Environment, Social, and Governance), supports the UN Sustainable Development Goals and covers a set of environmental, social, and governance factors that enhance a company's ability to create value, while respecting both the environment and people (ATHEX, 2024).

The related goals are expressed and monitored through specific Key Performance Indicators (KPIs). These indicators are valuable in expressing goals and performance in unambiguous and quantitative form. They are used not only to assess the performance of farms or countries, but also to compare pre-existing practices with new ones and to inform decision making. KPIs in agriculture are developed by researchers, institutions, or farmers aiming to assess their practices' effectiveness (Baris B. et al., 2024). Due to their variety and specificity, identifying suitable KPIs requires thorough research. If appropriate indicators are not available, it becomes necessary to develop new, quantifiable, and clearly defined KPIs that adequately address the specific requirements and objectives identified. The European Union has established a set of 48 agricultural indicators, titled "Context Indicators (CMEF)," to assess the Common Agricultural Policy (CAP) objectives, categorized into socio-economic, sectoral, and environmental dimensions. These indicators focus on productivity, profitability, energy consumption, environmental impact, crop health, soil health, resource efficiency, equipment performance, and data analysis.

In this research, we considered the KPIs related to sustainability in agriculture, to adopt the most suitable ones in the information model of the proposed CRM. The study focuses on precision agriculture services, therefore, the selected indicators must pertain to specific precision agriculture activities, through which modern practices can be evaluated and compared to traditional ones. To identify suitable KPIs, a web search was performed using keywords such as "KPIs," "agriculture," "precision agriculture," and "indicators." It should be noted that the search was not restricted to indicators published by official bodies; however, they needed to meet the necessary criteria to be

considered effective for drawing conclusions regarding agricultural activities. In particular, they are specific, measurable, achievable, realistic, and time-bound (Goula G., 2024). In Table 1, we present a set of selected KPIs which were found to be the most relevant for monitoring customised precision pesticide spraying processes.

**Table 1.** *KPIs relevant for monitoring precision pesticide spraying processes*

| Category                 | KPI                                      | Unit                                                                  | Estimated concept                                                            |
|--------------------------|------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------|
| Productivity             | Production per area                      | kg/1000m <sup>2</sup> or tn/ha                                        | Efficient use of land                                                        |
| Profitability            | Gross profit margin                      | % [(Revenue-Cost of sold products)/Revenue]*100                       | Profitability of product                                                     |
| Energy use               | Energy consumption                       | kWh/produced unit                                                     | Energy demands for production                                                |
| Environment              | Carbon footprint                         | kg CO <sub>2</sub> /product unit or kg CO <sub>2</sub> /ha            | Greenhouse gas emissions related to agricultural activity                    |
| Crop health              | Monitoring of health and stress of crops | Various indicators such as NDVI, Chlorophyll Levels, Leaf Temperature | Timely intervention in case of diseases, parasites and nutrient deficiencies |
| Soil health              | Soil Health Indicator                    | Soil moisture (%), nutrient content (ppm)                             | Quality of irrigation and crop fertilization                                 |
| Resource usage           | Irrigation Performance                   | L or m <sup>3</sup> /ha                                               | Reduction of water waste                                                     |
| Performance of machinery | Machinery Utilization and Efficiency     | Operation Hours, Fuel consumption (L/h)                               | Reduction of operational costs and increase of productivity                  |
| Data Analysis            | Data Integration & Analysis              | Data processing speed, prediction accuracy                            | Decision support for improving performance                                   |

### 3.2 Literature review in precision spraying

According to Katekar and Chekuru (2022), drone technology and artificial intelligence (AI) assist in addressing traditional challenges associated with agriculture. The conventional method of pesticide spraying poses a high risk to farmers' health due to continuous exposure to toxic substances, whereas the use of spraying drones saves time, reduces the environmental footprint of agriculture through the minimal use of crop protection products, and lowers costs while simultaneously increasing production (Katekar V. & Chekuru K.J., 2022).

Variable Rate (VR) technology represents another dimension of precision spraying with the use of unmanned systems, delivering immediate results in reducing resource usage. This type of technology

enables farmers to apply crop protection products, at varying rates based on real-time data and specific requirements (Getahun S. et al., 2024). For the effective application of variable-rate spraying with unmanned aerial vehicles, seamless real-time transmission of crop-related data is essential. This entails the need for connectivity between the sensors monitoring each crop and the use of advanced analytics (Zervopoulos A. et al., 2020). At the predictive level, artificial intelligence allows for optimal crop management and contributes to precision agriculture through its forecasting capabilities (Getahun S. et al., 2024).

## 4. Primary research

### 4.1. Observational research of existing IT systems in precision agriculture

According to Oladotun Okediran (2019), agriculture is an information-intensive sector where farmers heavily rely on accurate and timely information for crop management and effective exploitation. As agriculture evolves within an increasingly data-driven framework, various types of information systems have emerged. These systems not only provide insights into production but also support agricultural marketing, product pricing, logistics, trade, and finance. Two important categories of such systems are Agriculture Information Systems (AIS) and Farm Management Information Systems (FMIS). Agricultural Information Systems (AIS) are integrated systems that meet farmers' agricultural information needs (Vajjhala N. R., 2021), while Farm Management Information Systems (FMIS), which are considered an extension of AIS, not only provide information but also support essential operational processes related to crop management. FMIS focus on production efficiency, cost reduction, compliance with standards, and quality assurance (Fountas S. et al., 2015). Between 2018 and 2020, only 52 different FMIS were sold to 569 users (Melzer M. et al., 2023).

Other categories of specialized systems in agriculture are the ones related to precision agriculture processes. With the advancement of technology, traditional spraying has been replaced by precision spraying, which targets specific areas in need, controls flow rate, spray distribution, and start/stop timing (The SNP, 2019). To ensure the effectiveness of precision spraying, specialized digital systems have been developed, collecting data from various sensors to optimize the spraying process. Specifically, soil sensors, unmanned spectral imaging systems, and other technologies are integrated to assess crop-specific needs and generate tailored spraying programs. The following tables present the main commercial and research-based information systems that support precision agriculture, particularly drone-enabled precision spraying.

**Table 2.** *Commercial Information Systems.*

|                     | Architecture                                                                                                                      | Acquisition Method | Company     | Type / Version               | Desired Features    | Desired Services       | Cost                                                             |
|---------------------|-----------------------------------------------------------------------------------------------------------------------------------|--------------------|-------------|------------------------------|---------------------|------------------------|------------------------------------------------------------------|
| Tribble Ag Software | User-friendly interface, Farm management, planning/execution and analysis of cultivation processes, data sharing between devices. | Cloud              | PTx Trimble | Trimble Ag Software Business | Crop Health Imagery | Email Software Support | Farmer Starter – Free<br>Farmer Core - \$340+VAT<br>Farmer Pro - |

|                   |                                                                                                                                                         |       |              |                                       |                                                                                                                    |              |                                                                             |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-------|--------------|---------------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------|
|                   |                                                                                                                                                         |       |              |                                       |                                                                                                                    |              | \$2700+VA<br>T                                                              |
| FieldAgent        | User-friendly interface, crop needs analysis, farm health reporting, forecasting based on weather conditions                                            | Cloud | Sentera      | 2022                                  | Terrain Informed Flight Planning, image mosaics, real-time mapping, climate FieldView reporting, DJI compatibility | User support | Scout - \$1000/y<br>Advisor- 1500/y<br>Advanced- 3500/y<br>Enterprise       |
| Agremo            | User-friendly interface, creation of mosaics from aerial photographs, generation of crop management reports, creation of variable rate application maps | Cloud | Agremo       | Agremo Crop Monitoring                | VRA tool, compatibility with DJI products, comparison maps, spray application maps                                 | -            | Light Package - \$1250<br>Pro Package - \$3650<br>Advanced Package - \$4950 |
| Agroplanning      | User-friendly interface, ease of use, digitization of agricultural processes, personalized solutions, remote accessibility                              | Cloud | Agroplanning | My Agroplanning                       | My Agroplanning, connectivity with agricultural vehicles, geolocation, fleet management, API integration           | -            | Personalized offers                                                         |
| DJI SmartFarm app | User-friendly interface, agricultural field mosaics, prescription maps, compatible only                                                                 | Cloud | DJI          | DJI Smartfarm App & DJI Smartfarm web | Variable rate application tools for spraying and fertilization, drone flight plan creation, AI algorithms          | User Support | Offered as a service with the purchase of DJI equipment                     |

|             |                                                                                                                      |       |             |                    |                                                      |   |                                                                                               |
|-------------|----------------------------------------------------------------------------------------------------------------------|-------|-------------|--------------------|------------------------------------------------------|---|-----------------------------------------------------------------------------------------------|
|             | with DJI equipment                                                                                                   |       |             |                    | for crop monitoring                                  |   |                                                                                               |
| DroneDeploy | User-friendly interface, real-time data transmission to all users, area mapping, extraction of crop-related insights | Cloud | DroneDeploy | DroneDeploy Aerial | Offline usage, DroneDeploy LiveMap, Crop Health Maps | - | Individual: Individual \$349/month & Advanced \$649/month<br><br>Teams: Projects & Enterprise |

**Table 3.** *Research-based information systems*

|                                                  | Architecture  | Acquisition Method            | Desired Features                                                                                                | Special Characteristics                                                               | Purpose                                       | Tested or Not                                       |
|--------------------------------------------------|---------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------------|
| Nikkilä, R. et al.,2010                          | FMIS          | Remote server via web browser | Metadata management, ISOBUS intergration, multi-user support                                                    | Multiple RDBMS, secure interfaces, real-time data                                     | Support precision agriculture management      | Spraying of hordeum vulgare barley                  |
| RupniK R. et al.,2019                            | Modular DSS   | Web-based input by farmers    | Predictive modeling, data mining, simple UI, REST API                                                           | CRISP-DM process, visual feedback, pest population-based spraying                     | Decision support for precision agriculture    | Case study of spraying based on parasite population |
| Vanezi, E. et al.,2023                           | DSS           | Web-based                     | Alerts, crop tracking, weather link, dashboard, routine-based advice                                            | WordPress CMS based, global DB, weather API, modular plugin system                    | Decision support for small-scale farmers      | Tested                                              |
| Pechlivani, E.-M. et al.,2023<br>-<br>PestNu DSS | 3-layered DSS | Cloud-based                   | Real-time data, visualization, AI-driven decision support, pest/nutrient analysis, alerts, strategy suggestions | AI analysis blockchain verification, MongoDB, cybersecurity layer, multi-source input | Decision support for pest/nutrient management | Not Mentioned                                       |

Following an analysis of key agricultural information systems, we conclude that the essential features an FMIS or DSS should possess for effective crop management include:

- GIS integration
- IoT connectivity
- weather monitoring
- API service incorporation
- interoperability with other systems
- soil and crop data management
- report generation
- historical data tracking
- vegetation index mapping
- real-time information delivery
- equipment location tracking
- variable rate spraying prescriptions
- drone flight planning
- damage assessment
- 3D mapping
- data protection
- alert systems
- data sharing between devices
- offline connectivity.

These features collectively enhance precision farming, decision-making efficiency, and resource optimization in modern agricultural operations.

#### **4.2. Qualitative survey on user requirements**

The requirements elicitation process for the development of the CRM information system was conducted through an interview with a representative of a company active in aerial spraying services with drones. The interview was structured around a questionnaire organized into the following thematic categories: general information regarding user needs, field management with an emphasis on mapping and analysis, planning and execution of spraying operations, monitoring and control, financial management and reporting, user access and role definition, as well as technical requirements with provisions for support and training. Within this framework, three principal categories of end users were identified. Individual farmers constitute the first category, utilizing the system to access crop-related data, assess field conditions, and schedule spraying interventions. The second category comprises agricultural cooperatives, which leverage the system to coordinate collective actions and enhance operational efficiency. Finally, research institutions such as universities and agricultural institutes represent a third group of end users, employing the historical data of spraying activities for scientific analysis and the advancement of innovative agricultural practices. Internal users encompass drone operators, the analysis and strategic planning division, operational and administrative support staff, technical equipment specialists, customer support representatives, financial officers, system administrators, and agronomist-consultants. External stakeholders include suppliers, governmental

authorities, local agencies, and certification bodies, who connect to the system via secure digital interfaces. According to the interviewed representative of the company, the most important user roles are the Spraying company representative, the Farmer, the Agronomist, and the Drone operator. The functional requirements identified include scheduling and coordination of spraying operations, data collection and management, client relationship management, report generation, real-time data distribution, invoicing, access control, equipment tracking, and user activity logging. Complementarily, the non-functional requirements address dimensions of performance, reliability, scalability, regulatory compliance, interoperability, maintainability, adaptability, cost optimization, and robust security. Together, these specifications delineate a system architecture designed to be both operationally efficient and strategically sustainable, thus aligning with contemporary standards of digital agriculture and enterprise information systems.

#### **4.3. Experimental evaluation of sustainability indicators**

An experimental study was conducted to verify the relationship between spraying practices using drone technology, water consumption, and energy efficiency. The equipment employed for the measurements included the DJI Agras T30 drone and a conventional spraying unit. The results demonstrated that traditional spraying consumed approximately 21.5 times more water per stremma compared to drone-assisted spraying, thereby confirming the latter's significant potential in reducing water waste in agricultural applications. Furthermore, the ability of drones to deposit spraying solutions with precision in targeted areas, while also accessing difficult terrain without exposing farmers directly to chemical agents, highlights a promising method that actively supports the principles of sustainable agriculture.

The analysis also revealed notable differences in energy performance. Drone-assisted spraying was found to consume approximately 6.25 times less energy than conventional spraying, underscoring its superior energy efficiency. In addition, drone operations rely exclusively on electricity, thus avoiding direct CO<sub>2</sub> emissions, in contrast with traditional spraying machinery powered by gasoline or other fossil fuels. This constitutes a critical advantage in efforts to minimize agriculture's carbon footprint.

Nonetheless, the study faced certain limitations, including measurement accuracy, experimental conditions, test duration and repetitions, the influence of human factors, and the possibility of equipment malfunctions, which should be addressed in future research to strengthen the validity and generalizability of the findings.

### **5. Results**

The proposed system should by its nature be flexible and extensible regarding information management, business logic and communications, therefore a 3-tier architecture was considered the most suitable. As shown in Figure 2, in the Data tier there is provision for a dedicated local database, cloud storage and link to external data sources through APIs, while in the Client tier it is foreseen to provide interfaces with desktop and web users, as well as communication with drones.

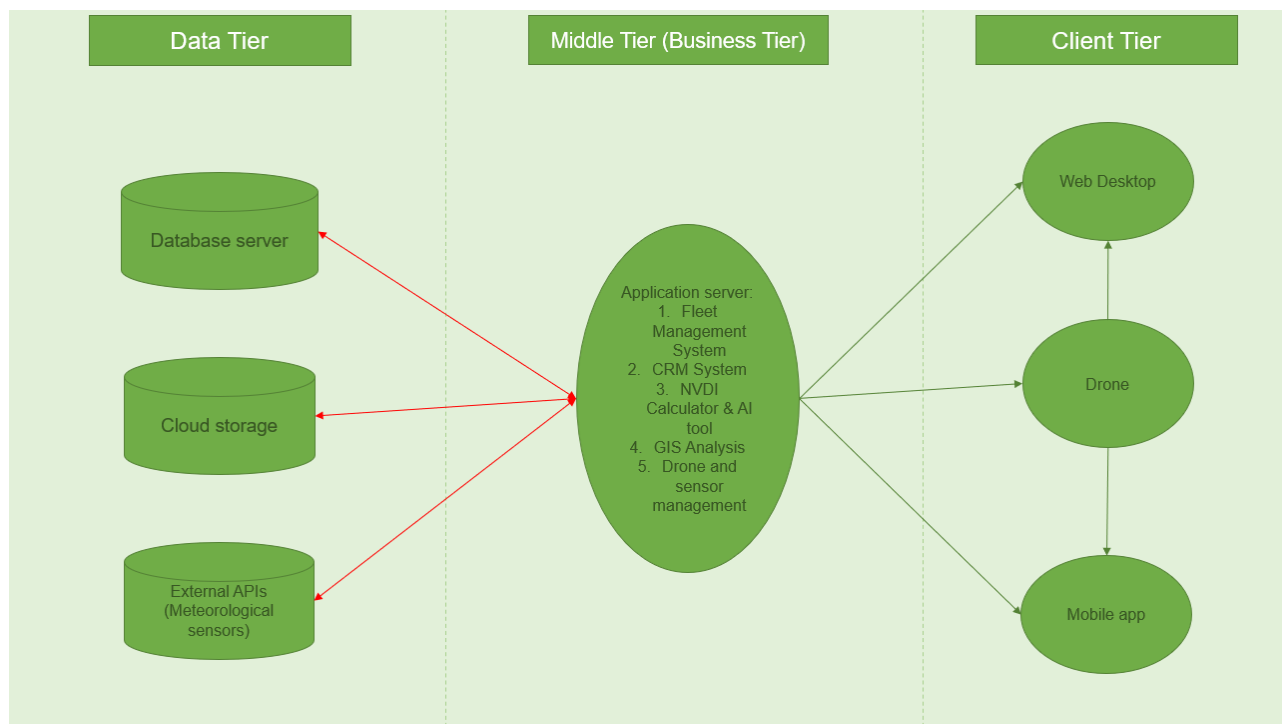


**Figure 2.** The proposed 3-tier architecture.

Following the observational research on existing systems and based on the qualitative survey with potential users, the functional requirements were specified for the proposed system. The most important use cases are presented in the Use Case diagram in Figure 3 and in Table 4.

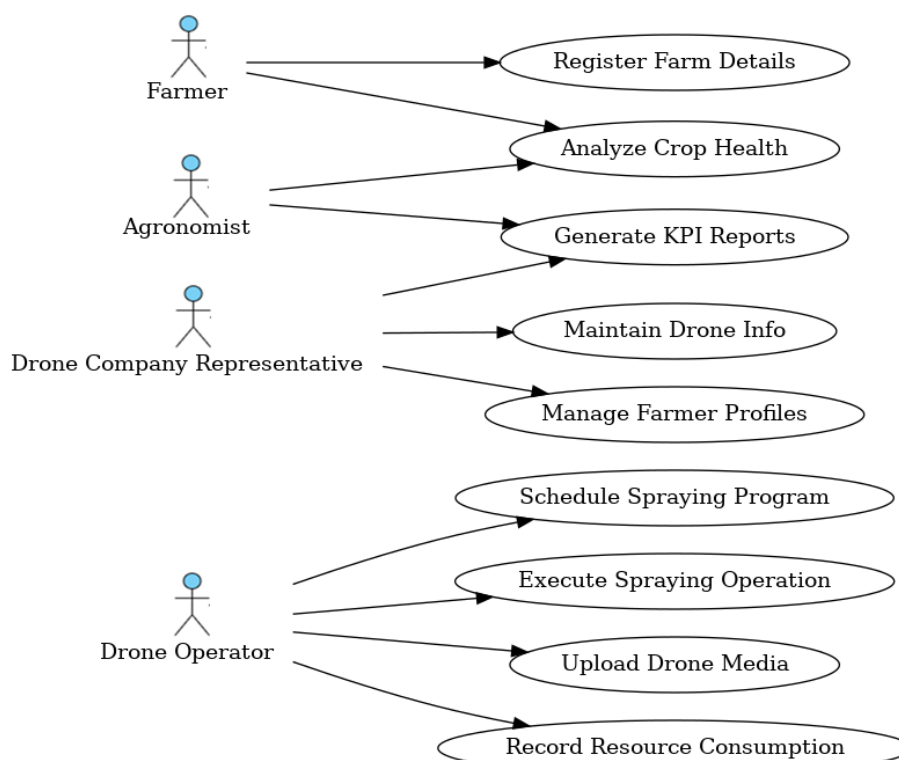


**Figure 3.** Use case diagram of Agricultural CRM.

**Table 4.** *Important use cases of the Agricultural CRM.*

|    | Use case                                                                                      |
|----|-----------------------------------------------------------------------------------------------|
| 1  | Generating customized spraying schedules based on past spraying history and crop health data. |
| 2  | Evaluating spraying program efficiency through KPIs.                                          |
| 3  | Using drone imagery to detect issues and refine future spraying.                              |
| 4  | Reporting environmental impact (e.g. pesticide drift near sensitive areas).                   |
| 5  | Tracking customer interactions and improving service personalization.                         |
| 6  | Scheduling and coordination of spraying operations                                            |
| 7  | Exploitation                                                                                  |
| 8  | Customer management                                                                           |
| 9  | Report generation                                                                             |
| 10 | Communication with users                                                                      |
| 11 | Data sharing                                                                                  |
| 12 | Invoice issuance                                                                              |
| 13 | Access control                                                                                |
| 14 | Equipment location tracking                                                                   |
| 15 | Action logging                                                                                |

A conceptual information model was also produced to summarise the main data components that must be collected and maintained in the CRM (Figure 4). The main entities in this model are Farmer (customer), Farm, Spraying program, Drone, Spraying history, Crop health feedback, Drone media, Resource consumption, Performance metrics (KPIs).

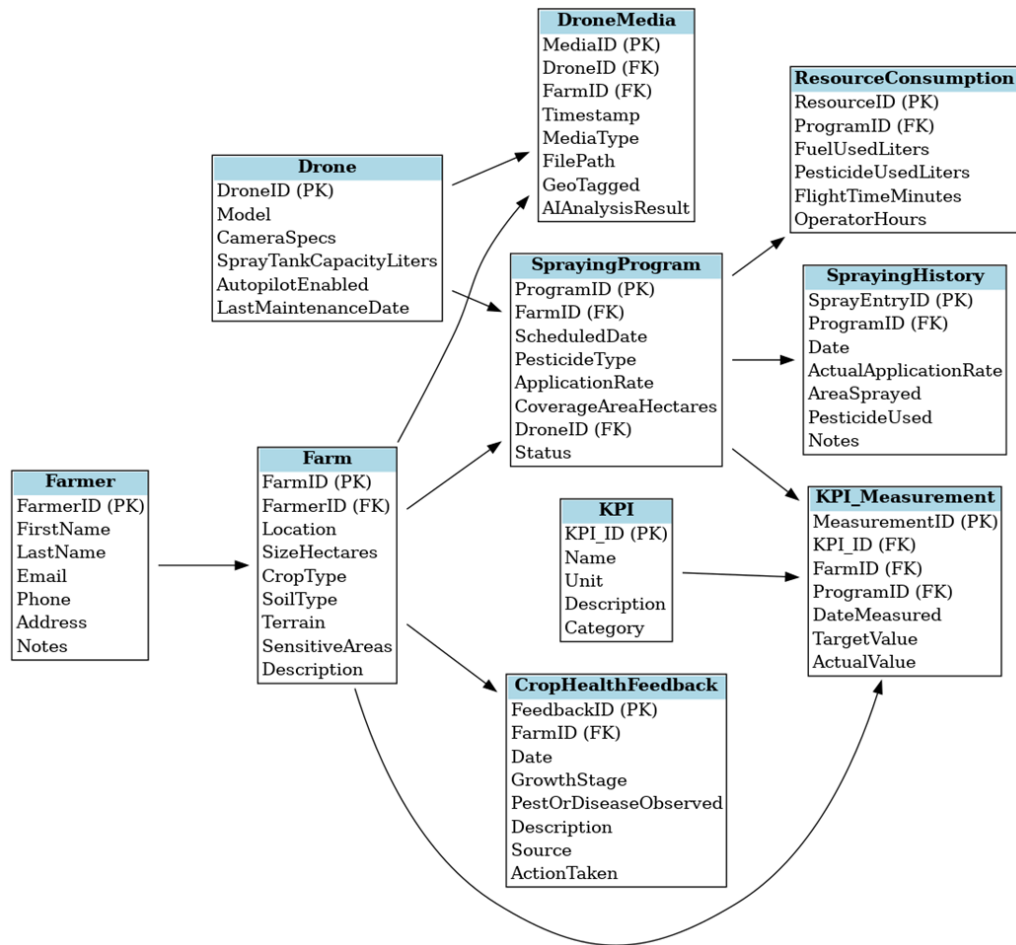


Figure 4. Conceptual information model.

## 6. Conclusions and discussion

Reducing agriculture's environmental footprint while adopting modern practices that enhance farmer engagement and improve crop productivity must form the core of sustainable agricultural development. To assess the sustainability of agricultural operations, the use of Key Performance Indicators (KPIs) is essential, enabling the evaluation of current cultivation practices and highlighting areas requiring transformation. In this context, the spraying process was examined through a comparative study between conventional spraying methods and drone-assisted spraying. The results confirmed that drone technology significantly improves sustainability, reducing water consumption by approximately 21.5 times and energy use by 6.25 times, while simultaneously protecting farmers from direct exposure to chemical agents, thereby improving workplace safety and health.

The study further highlights the broader potential of integrating precision agriculture technologies with dedicated Information Systems. Such systems allow the creation of customized drone-spraying programs, the compilation of historical datasets, and automated reporting, all of which enhance decision-making and optimize resource use. The design of the proposed agricultural CRM system demonstrates how specialized software can drive substantial innovation, supporting environmentally responsible, economically efficient, and socially safe agricultural practices. In regions such as Greece, regulatory limitations have slowed the adoption of drone spraying, yet international examples show the potential benefits of these technologies. Future research should focus on practical trials, cost-benefit analyses, and actions towards farmers' acceptance of precision spraying technologies, while regulatory adaptations will be essential to fully realize sustainable, high-efficiency drone-assisted agriculture.

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## **Cost of quality in the organic food sector: the case of Greece**

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### **Extended Abstract**

#### **Purpose**

In the present paper emphasis is placed on the Cost of Quality processes in the organic food sector of Greece. Organic products are characterized by their high quality, because they are produced by safer methods (without pesticides, fertilizers, antibiotics or genetically modified organisms), helping the sustainable development and protection of the environment and animals. In this context, the research in the area of organic products is of great importance. More than their consumption, it is their cost of quality, analysed in the PAF Model categories (Prevention, Appraisal, Failure), that is of interest in this paper, in order for organic products to be competitive in terms of quality and price. Organic food is produced according to modern standards and methods of organic agriculture, based on natural processes, without the use of chemical synthetic fertilizers, hormones, antibiotics and pesticides. Quality and its cost are considered as the main criteria of consumer and business behavior. Consumers are no longer concerned so much with the quantity of products or services as with their quality. Therefore, businesses strive to build competitive qualitative products, that will not only be preferred by consumers, but which will also result in increased sales and profits in this turbulent financial environment.

#### **Methodology**

A survey on the cost of quality was conducted with the use of a structured questionnaire among 127 producers of organic food in Greece. The questions were categorical and had a 3- 5- point Likert scale. The analysis of the data has been conducted with the use of Linear Regression. Linear Regression analysis was utilized as a tool to identify correlations between the cost of quality and demographic characteristics of the producers, such as company size and quality assurance practices. The demographic characteristics that have been set as the following independent variables follow:

Q1 - Company Sector

Q2 - Quality Assurance Department

Q3 - Level of Education

Q4 - Number of Employees

Q5 - Annual Turnover

Questions 14, 16, 18 and 20 of the questionnaire, related to the cost components of each prevention-appraisal-internal/external failure cost category and the level of prevention-appraisal-internal/external failure costs, were used as the dependent variables of the research.

## Findings

As far as the level of investment on the Cost of Quality categories is concerned, the findings show a definite focus on prevention and appraisal activities, which lead to low investments in failure costs. Companies that effectively integrate quality costing strategies are better positioned, in order to maintain competitiveness and profitability in this demanding environment. The following Tables 1, 2, 3 and 4 show the results of the cost analysis.

**Table 1:** *Prevention Costs*

|       | Prevention Costs                                                                                              | 0-500 € | 501-1000 € | 1001-5000 € | Over 5000€ |
|-------|---------------------------------------------------------------------------------------------------------------|---------|------------|-------------|------------|
| Q14_1 | Certification of a field as organic farming                                                                   | 18      | 87         | 22          | 0          |
| Q14_2 | Training and specific staff expertise on organic products                                                     | 89      | 14         | 24          | 0          |
| Q14_3 | Strict limits on the use of synthetic fertilisers and pesticides                                              | 36      | 65         | 26          | 0          |
| Q14_4 | Quality planning and organisation / intercropping (rotation of crops in the same field)                       | 51      | 45         | 31          | 0          |
| Q14_5 | Special field design and organisation to reduce environmental pollution and maintain soil and water integrity | 94      | 9          | 24          | 0          |

**Table 2:** *Appraisal Costs*

|       | Appraisal Costs                                                      | 0-500 € | 501-1000 € | 1001-5000 € | Over 5000€ |
|-------|----------------------------------------------------------------------|---------|------------|-------------|------------|
| Q16_1 | Inspections, controls, testing of incoming raw materials, seeds      | 73      | 24         | 18          | 12         |
| Q16_2 | Inspections, controls, testing of intermediate and finished products | 24      | 54         | 36          | 13         |
| Q16_3 | Checking and renewal of certifications                               | 1       | 90         | 36          | 0          |
| Q16_4 | Supplier assessment and inspection                                   | 60      | 17         | 18          | 32         |
| Q16_5 | Equipment maintenance and quality control                            | 25      | 18         | 65          | 19         |

**Table 3:** *Internal Failure Costs*

|       | Internal Failure Costs                               | 0-500 € | 501-1000 € | 1001-5000 € | Over 5000€ |
|-------|------------------------------------------------------|---------|------------|-------------|------------|
| Q18_1 | Cost of scrap materials (scrap)                      | 86      | 10         | 13          | 18         |
| Q18_2 | Cost of defective products                           | 68      | 31         | 28          | 0          |
| Q18_3 | Production of new products to replace defective ones | 81      | 12         | 34          | 0          |
| Q18_4 | Re-testing of products                               | 62      | 23         | 40          | 2          |
| Q18_5 | Analysis of causes for internal failure              | 77      | 37         | 12          | 1          |

**Table 4:** *External Failure Costs*

|       | External Failure Costs                                         | 0-500 € | 501-1000 € | 1001-5000 € | Over 5000€ |
|-------|----------------------------------------------------------------|---------|------------|-------------|------------|
| Q20_1 | Cost of products not placed on the market due to unsuitability | 87      | 7          | 33          | 0          |
| Q20_2 | Order cancellations                                            | 85      | 8          | 24          | 10         |
| Q20_3 | Replacement cost                                               | 107     | 6          | 14          | 0          |
| Q20_4 | Civil liability and customer compensation                      | 127     | 0          | 0           | 0          |
| Q20_5 | Lost sales                                                     | 99      | 6          | 3           | 19         |

In addition, the Linear Regression analysis shows that the presence of a dedicated Quality Assurance Department within companies correlates positively with the implementation of a cost of quality system. Companies with such departments are more likely to implement effective quality control measures and training, leading to lower product costs and greater customer satisfaction. Furthermore, there is significant correlation between the cost of quality and the size of companies, measured by the number of employees. Larger companies tend to allocate more resources especially on appraisal costs, which lead to lower failure costs and lower product costs in general. The company sector demonstrates moderate influence on the cost of quality, with the exception of prevention and appraisal costs, where it plays a more meaningful role. Finally, the level of education and the annual turnover appear to have limited effect on the implementation of a quality costing system. The results are shown in summary below:

#### Q1: Company Sector

Significant for: Prevention Costs (Q14\_3), Appraisal Costs (Q16\_1, Q16\_3), Internal Failure Costs (Q18\_1, Q18\_3, Q18\_5), External Failure Costs (Q20\_1, Q20\_2)

Highest  $R^2 \approx 0.16$  (Q16\_3) – Appraisal Costs

Moderate to strong negative correlations (-0.3 to -0.5)

#### Q2: Quality Assurance Department

Highly significant across nearly all dependent variables ( $p < 1e-08$ )

Strongest  $R^2$  values (up to 0.431) - External Failure Costs Q20\_2)

Consistent strong negative correlations (up to -0.65)

Organizations with a QA department tend to report lower failure costs

Most influential independent variable

#### Q3: Level of Education

Generally non-significant ( $p > 0.05$  for most variables)

Low  $R^2$  (near zero)

Exceptions: External Failure Costs Q20\_5 ( $p \approx 5.7e-08$ )

Internal Failure Costs Q18\_4 ( $p = 0.008$ )

Weak or no consistent correlation

#### Q4: Number of Employees

Highly significant for External Failure Costs Q20\_3 ( $p \approx 7.55e-09$ ) and Q20\_5 ( $p \approx 9.54e-26$ )

Moderate  $R^2$ , strongest at Q20\_5 ( $\approx 0.5867$ )

Significant but weaker impact for: Prevention Costs Q14\_4, Appraisal Costs Q16\_4, Internal Failure Costs Q18\_4

#### Q5: Annual Turnover

Limited significance: only Q20\_5 ( $p \approx 0.0003$ ) shows clear influence

Low  $R^2$  overall; Q20\_5 reaches  $\sim 0.099$  (modest explanatory power)

Most relationships non-significant ( $p > 0.05$ )

#### Originality/Value

Since there are limited references in literature on the role that Quality Costing plays in the development and success of organic food sector in Greece, the present study offers a first insight into the attitude of Greek companies towards quality costing implementation and its relationship with their size, their activity or their emphasis on quality assurance processes.

**Keywords:** *Cost of Quality, Prevention - Appraisal - Failure, PAF Model, organic food sector.*

# **Total quality management in the public sector of Greece - the case of primary education in the region of Eastern Macedonia – Thrace**

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## **Abstract**

Total Quality Management is a holistic operating framework that includes both principles and techniques that are applied to an organization in order for it to integrate quality at all its stages. In this way, errors are minimized, costs are reduced, the working environment for employees is improved and higher quality services are provided to citizens who are the recipients of public organizations' production. Many studies to date demonstrate the successful contribution of TQM in the effort to modernize such organizations in many countries. In the case of this paper, a primary quantitative study was conducted aiming at determining whether TQM tools are successfully applied in a specific public organization in Greece and whether specific demographic characteristics influence the opinions of employees. It was shown that demographic characteristics do not particularly differentiate employees' perception of the level of quality that TQM brings to the organization they work for, while a factor that seems to differentiate these opinions is their working experience.

**Keywords:** *Total Quality Management (TQM), public organizations, effectiveness, employees*

## **1. Introduction**

Total Quality Management (TQM) is a holistic framework of techniques and principles developed to help ensure a high level of quality in production processes. More specifically, the basic philosophy of TQM states that quality must be the focus of every stage of production of a product or provision of a service in order to ensure the minimization of errors, delays and equivalent costs, as well as to increase sales, revenues and customer satisfaction (Muhamad, Kamis & Jantan, 2003). The great success of TQM in its application in private enterprises contributed to promoting its adoption by public organizations (Carol Rusaw, 2007; Liveris, 2015). In particular, the challenges that characterize the public sectors in many countries, including Greece, are numerous and tend to be perpetuated. This situation led to high inefficiency, financial deficits, dissatisfied employees and generally unproductive public organizations, which were unable to serve the common good for which their operation is organized (Rocha & Zavale, 2021). In this light, those in power in recent years have sought to identify techniques whose implementation will address these problems and lead to a renewed culture with an emphasis on the employee, the citizen and every interested party. As demonstrated by many studies and research over the years, the IOP is an excellent such tool (Gomes, Small & Yasin, 2019).

It has even been proven that when the TQM is implemented correctly, employee productivity is boosted, relationships in the work environment are improved, the organization's goals become more

understandable, ultimately resulting in better service to the customer, that is, the citizen (Tuomi et al., 2013; Psomas et al., 2017). For Greek data, the limited number of studies that have taken place on this issue demonstrates that while an attempt is being made to implement the TQM in Greek public organizations of various sectors, the goals at which the TQM aims are not sufficiently clear, and the training that employees receive on this issue is not sufficient or satisfactory for them to be able to contribute to the success of the TQM (Psomas et al., 2017; Oikonomidou & Konstantinidis, 2019; Baroutas et al., 2020).

In this work, it is investigated whether employees of different demographic characteristics differentiate their answers and therefore perceive differently the degree of effective implementation of the TQM within the organization they work for the public Greek sector.

This work includes four sections. The first section presents the theoretical background of Total Quality Management, developing what its philosophy includes, what are the benefits that arise from its successful implementation. The second section refers to the methodology of the research that was followed. Specifically, the research objective is recorded, the individual research questions are listed, the research tool is described, the population and the sample are defined and finally, the statistical tools used for data processing and results extraction are presented. The third section presents the results of the research. The fourth section presents the main findings of the primary research that was conducted and a relevant discussion is made, including the conclusions of both the theoretical and research parts of the work. At the end of this chapter, a list of bibliographic sources used in the work is provided.

## **2. Literature review**

### **The concept of quality in modern business**

The concept of quality is increasingly of concern to both academics and business people. The reason is that in the modern era, in the organized framework of markets, there is a great abundance and completeness in products, but now also in the services that are provided and sold. In many cases, the supply is objectively large and tends to exceed demand, resulting in increased competition between producers. Therefore, in the effort of businesses and organizations to cope, on the one hand, with demand and its specifications set by consumers, and on the other hand with the movements of competitors, which are often sophisticated and constitute progress for an industry, the concept of quality is the key to their competitive profile (Ezrachi&Stucke, 2015).

In reality, a business aims to increase sales, profitability, customer base and thus its market share in the industry in which it operates. This means that it should place great emphasis on what customers ask for and what requirements they have regarding the specifications they expect the product or service they buy to have. Therefore, from this perspective in competitive markets, the ultimate goal is to satisfy customer requirements in a way that is considered rational, that is, to be achieved with the realistic means, resources and knowledge available to an organization (Al-Bourinie et al., 2013). In this way, the concept of quality is practically defined. Although its definitions have varied over time, quality nevertheless encompasses specific properties and elements.

### **The philosophy and characteristics of QMS**

In reality, the focus on quality and its integration into the development of production processes can be seen as early as the early twentieth century. The initial theories of Management gradually began to include the concept of controlling and ensuring quality products through properly organized processes and production lines. Over the decades, the development of technology contributed greatly to the intensification of this effort, with the result that in the 1950s Deming taught Japanese companies the great value that statistical analysis and quality control had for their efficiency. During the same

period, other enlightened scientists-executives such as Juran and Crosby taught the value of quality control and the emphasis on a production with zero defects, respectively. This is how the so-called Total Quality Management (TQM) began, which although it took a few more decades to be considered a comprehensive management theory, since 1980 it has been considered a holistic management system that is integrated into the strategy and way of operating an organization, with an ever-increasing use of Standards such as ISO 9000 (Fisher & Nair, 2009). TQM is thus considered a more general philosophy that emphasizes the development of management methods (plan) to maximize the perceived value of the product, given that all processes that take place for its production involve the participation of employees (Tsiotras, 2022). Particular emphasis is placed on cost minimization, which as a parameter does not refer to the limitation of resources that entail expenses for the company, but to their proper utilization without problematic processes, delays, errors or defective products. To do this, the DPO itself provides a basic concept on which the quality that its entire philosophy provides focuses, continuous improvement (Mitrevva et al., 2020; Sharma & Rahim, 2021).

### **The advantages of implementing TQM in public organizations**

As mentioned in a previous section, public organizations in many countries, including Greece, face many challenges and problems regarding their efficiency and financial health. The usual characterizations they have carried over time are loss-making and ineffective, which by nature indicate a lack of quality in the way in which daily processes are carried out, in the outputs that flow from these organizations (i.e. the services that citizens enjoy) and more generally in the culture that has developed and governs them (Liveris, 2015).

It was also mentioned above that the implementation of TQM and its integration into the philosophy of public organizations encounters challenges and obstacles due to the different nature of the public organization from the private enterprise. However, the benefits derived from its implementation are also multiple and consistent with what the New Public Administration defines for the modernization and consolidation of public organizations (Rocha & Zavale, 2021). The primary advantage is the promotion of the productivity of the public organization. In general, the DPO supports the logic of continuous evolution and the minimization of errors and problematic procedures in a way that serves employees not to encounter obstacles in their work and thus makes it easier for them to perform their duties to serve the citizen (Boyne & Walker, 2002). The establishment of processes that will entail the removal of obstacles at each stage of service production and the smooth work and execution of the duties of each job position is expected to increase the productivity of the organization as a whole.

An additional benefit resulting from boosting productivity is the reduction of obstacles that still exist today and arise due to bureaucratic and often meaningless procedures that are provided for a process to be executed.

Another important benefit that results from the implementation of the TQM in these organizations is the gradual increase in employee satisfaction and therefore their desire to work productively. Public organizations are certainly characterized as work environments with low productivity motivation as there are few cases where public employees are motivated to work productively (Oikonomidou & Konstantinidis, 2019).

## **3. Methodology**

### **Presentation of the purpose and research questions**

The research was conducted that will be designed appropriately to answer the research questions that will be posed. Thus, the purpose of the research is to study the implementation of Total Quality Management in Primary Education in the Region of Eastern Macedonia - Thrace. The investigation

of this issue in the specific Primary Education Directorates arose within the context of the general need to investigate the implementation of Total Quality Management in the Greek public sector. The research questions that were raised and will be studied in the next chapter are the following:

- 1) Is there a significant difference in the responses of male and female employees regarding the implementation of Total Quality Management in the Primary Education Directorate where they work?
- 2) Does the age of employees significantly differentiate their answers regarding the implementation of Total Quality Management in the Primary Education Directorate where they work?
- 3) Is there a significant difference in the opinions of employees regarding the implementation of Total Quality Management based on their family status?
- 4) Does the educational level of employees significantly differentiate their answers regarding the implementation of Total Quality Management in the service where they are employed?
- 5) Does the years of service of employees constitute a factor in significantly differentiating their answers regarding the implementation of Total Quality Management in the Directorate where they work?
- 6) Is there a significant correlation in the opinions of participants on different quality factors within the Primary Education Directorate where they are employed?

### **Selection of research type and methodological steps**

In order to carry out this primary and quantitative research, a questionnaire has been developed that is appropriately structured so as to facilitate the answer to the research questions. This consists of 48 closed-ended questions and two open-ended questions organized into two sections, the first includes a series of questions related to the issue of total quality management and its implementation within the organization and the second includes the demographic data of the respondents. The first section results from groups 7 (Staff) and 9 (Organization) of the proposed questionnaire by E. Sallis (2002) for determining the level of quality and its implementation techniques.

The research conducted has been carried out using non-probability sampling. This is because, on the one hand, the researcher does not have access to the staff of the Primary Education Directorates of the Eastern Macedonia - Thrace Region and, on the other hand, because the time to carry out the thesis is limited and is not enough to reach the entire population.

### **Population and sample**

The population of this study was taken as all employees in the Primary Education Directorates of the Eastern Macedonia - Thrace Region. However, because their number is quite large and the study of the population would be quite time-consuming, a smaller sample of 45 individuals was selected. As shown in Figure 1, the largest percentage consists of women (66.7%) while men participated in a percentage equal to half of that of women (33.3%).

## **4. Results**

### **Results of descriptive statistics**

The first section of the results lists the descriptive measures of the responses given by the participants to each of the propositions concerning Total Quality Management in the Primary Education Directorates of Eastern Macedonia - Thrace. At the same time, the descriptive measures of the total scores given by the participants to each group of propositions are given. It is worth noting that the reason for choosing the specific descriptive measures (minimum value – E.T., maximum value – M.T., average – M.O., standard deviation –  $\Sigma.A.$ ) is the Likert scale that exists in the responses to each proposition (0: Not at all, 1: Minimally, 2: A little, 3: Quite a bit, 4: A lot, 5: Very much).

Initially, the descriptive measures of the responses and the total scores on the proposals and groups of proposals concerning Quality as reflected by the employees are presented. The results are listed in Table 2.

As can be seen, the participants largely agree that the staff working in the Primary Education Directorates of the Eastern Macedonia - Thrace Region have an approach focused on the school units (M.O.=4.00, SD=0.83). Also, the employees responded, in general, that the staff responds very well to the individual needs of the school units (M.O.=3.91, SD=0.90). On the other hand, the participants stated to a lesser extent that the staff is happy about the subject of their work (M.O.=3.31, SD=1.06). However, in general, it seems that the Primary Education Directorates of Eastern Macedonia - Thrace are characterized by a positive image regarding the attitude and motivation of employees (M.O.=22.71, SD=4.52).

Then, the opinions regarding the teamwork of the employees were studied. The greatest agreement was in the clear perception of each group for the limits of its responsibility (M.O.=3.60, SD=1.23) and in the existence of a team spirit of dedication to teamwork (M.O.=3.58, SD=1.12). On the other hand, the employees expressed a moderate degree of availability of resources that allow them to improve the level of their work (M.O.=2.96, SD=1.35). Finally, a similar picture was observed in terms of seeking the opinion of the team regarding the organization's policy (M.O.=2.82, SD=1.17). It is worth noting that in general, employees consider the implementation of Total Quality Management in the area of teamwork to be moderate (M.O.=19.29, SD=6.02).

The following suggestions concerned the development and training of personnel. As shown in Table 2, participants largely agreed that training includes all personnel (M.O.=3.67, SD=1.23). Subsequently, it appears that management tends to act proactively and clearly state the needs of the organization (M.O.=3.47, SD=1.16). It also seems to be largely true that staff training is a priority for the organization (M.O.=3.42, T.A.=1.18). On the other hand, participants seem to express moderate agreement that staff development begins with the recording of personal needs (M.O.=3.24, T.A.=1.23). Finally, the least positive views were noted in the statement that staff training has adequate resources and funding (M.O.=2.98, T.A.=1.25). Once again, it seems that participants generally express a moderate image regarding staff development and training (M.O.=23.49, T.A.=7.13).

The last proposals regarding Total Quality Management for employees refer to the facilities of each Primary Education Directorate. Initially, it appears that employees are, in general, very satisfied with the adequacy of equipment and facilities (M.O.=3.91, SD=0.87). Also, a positive picture was noted regarding the workspaces (M.O.=3.84, SD=0.93) and the opportunities for professional dialogue and discussion (M.O.=3.51, SD=1.14). It is worth emphasizing that the participants seem to be, overall, quite satisfied with the quality of the facilities (M.O.=11.27, SD=2.55).

### **Results of the inductive tests of difference by demographics**

The first section of the inductive tests concerns the possible significant differentiation of men and women in their answers regarding Total Quality Management factors (Attitude and motivation, Teamwork, Staff development and training, Facilities, Strategic planning, Organizational culture, Communications). Specifically, they are tested in the total scores they scored on the factors concerning the quality of employees and the organization in the Primary Education Directorates of the Eastern Macedonia - Thrace Region. In each case, the difference tests were carried out using the parametric test. t-test for 2 independent samples.

Men and women working in Primary Education Directorates of the Eastern Macedonia - Thrace Region do not affect the results and present approximately the same views regarding the attitude and motivation of the staff and teamwork. The same applies to the development and training of personnel and the facilities of the Directorate. Furthermore, the character of the Directorate in terms of strategic

planning and organizational culture seems to be evaluated in a similar way by both men and women. Finally, the two genders present approximately the same views regarding communication, knowledge management and the existence of quality tools and techniques in the organization.

Simultaneously no significance detected to the relationships among age, marital status, education level and the above mentioned factors.

On the contrary, the last inductive tests carried out concerned the possible significant correlation between the various factors of the research (6th research question). In this case, the Pearson Correlation coefficient was calculated. As shown in the following Table, almost all the factors of the research show a strong and significant positive correlation. The only exception is attitude and motivation, which shows a moderate correlation with communications with  $r=0.586$   $p<0.001$  and quality tools and techniques with  $r=0.568$   $p<0.001$ . This means that employees who show a higher overall score on one quality factor also express a higher overall score on the remaining factors. It is worth noting that the strongest correlations were between staff development and training with each of the quality factors of the organization ( $r>0.8$ ) in every case except strategic planning ( $r=0.770$ ,  $p<0.001$ ).

|                                | Attitude and motivation | Teamwork | Staff development and training | Facilities | Strategic planning | Organizational culture | Communications | Knowledge management | Quality tools and techniques |
|--------------------------------|-------------------------|----------|--------------------------------|------------|--------------------|------------------------|----------------|----------------------|------------------------------|
| Attitude and motivation        | 0.770***                |          |                                |            |                    |                        |                |                      |                              |
| Teamwork                       |                         |          |                                |            |                    |                        |                |                      |                              |
| Staff development and training | 0.721***                | 0.867*** |                                |            |                    |                        |                |                      |                              |
| Facilities                     | 0.676***                | 0.736*** | 0.832***                       |            |                    |                        |                |                      |                              |
| Strategic planning             | 0.604***                | 0.780*** | 0.770***                       | 0.739***   |                    |                        |                |                      |                              |
| Organizational culture         | 0.743***                | 0.825*** | 0.897***                       | 0.782***   | 0.844***           |                        |                |                      |                              |
| Communications                 | 0.586***                | 0.752*** | 0.816***                       | 0.673***   | 0.656***           | 0.842***               |                |                      |                              |
| Knowledge management           | 0.768***                | 0.841*** | 0.884***                       | 0.833***   | 0.736***           | 0.806***               | 0.761***       |                      |                              |
| Quality tools and techniques   | 0.568***                | 0.666*** | 0.806***                       | 0.711***   | 0.680***           | 0.699***               | 0.634***       | 0.790***             |                              |

## 5. Discussion and conclusions

TQM is a unified framework of techniques, principles and tools that, when applied correctly, is able to establish the entire philosophy of quality within the operation of an organization so that all processes carried out as well as the final outputs are characterized not only by high quality, but also by a continuous effort for further improvements and development. In order for the implementation of TQM to function properly, it requires and presupposes the existence of smooth communication within the organization without obstacles, the dedication of the leadership and, by extension, of employees at all levels and the development of a culture of quality throughout the organization. The above indicates that within public organizations, the TQM aims to cultivate a specific way of thinking, operating and making decisions as well as working of employees there that is governed by improvement, modernization and continuous development in an effort to ensure high quality at all stages of production of the services that each organization is called upon to provide to citizens.

The application of the TQM in public organizations in countries such as Greece that are trying to address their numerous problems and inadequacies is expected to offer multiple advantages and positive elements, such as for example the stimulation of staff productivity, the improvement of working conditions, the better service of interested parties. Various studies that have been conducted over time demonstrate the positive relationship that exists between the application of the DPO in public organizations and employee satisfaction, as well as their higher performance. Various factors

seem to contribute to this relationship, such as the role taken on by leadership within the framework of TQM, better organization, improved organizational culture, and others. At the same time, however, it is found that when these studies focus more on the implementation of TQM in the Greek public sector, the employees' views tend to be more moderate, as various issues are found that to this day constitute a brake on the proper implementation of TQM and therefore on its ability to produce the expected and desired results. Thus, recent studies conducted for Greek data support that the objectives that exist within the framework of quality are not clear, the training that staff receive is only partial, as well as that the organizational culture is not developed properly adapted to the philosophy of quality.

The analysis carried out to determine the degree of effective implementation of the Quality Management System in Greek public organizations and which employee characteristics differentiate the responses on the issue concludes that employees generally maintain a moderate attitude towards the areas of quality in the Primary Education Directorates of the Eastern Macedonia - Thrace Region. An exception is communication within the organization where they seem to be satisfied to a large extent. Their demographic characteristics (gender, age, educational level, family status) do not seem to affect their responses regarding quality within the Directorate where they are employed. However, experience is an important factor in differentiating their responses. Specifically, employees with less experience seem to be more satisfied with most quality factors. Furthermore, it is interesting to note that employees who have more positive views on one quality factor seem to have a better image of the other factors as well.

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## Reassessing presumptive taxation: Evidence from Greece

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### Abstract

Promoting voluntary tax compliance is a cornerstone of effective fiscal governance. Tax evasion not only deprives states of essential revenue—undermining their capacity to deliver public goods—but also distorts economic behavior, exacerbates income inequality, and erodes trust in the tax system (Slemrod, 2007). When taxpayers perceive enforcement as arbitrary or inequitable, willingness to comply diminishes (Kirchler, 2007). Building on the foundational economics-of-crime model by Allingham and Sandmo (1972) much of the literature has focused on tax audits as a deterrent to evasion. While audits can yield direct fiscal gains and indirect compliance benefits (Kasper and Alm, 2022), they are costly and difficult to scale—particularly in addressing compliance challenges among small and self-employed taxpayers, often considered “hard-to-tax” (Bucci, 2020).

In response, policymakers have increasingly turned to presumptive taxation regimes, which estimate tax liabilities using observable proxies—such as business type, assets, or location—rather than direct income assessments (Mas-Montserrat et al., 2023). These systems offer administrative efficiency by reducing audit dependence and simplifying enforcement, especially where recordkeeping is poor (Ferry, Evans and Tran-Nam, 2023). However, they are also susceptible to behavioral distortions and equity concerns. Taxpayers often manipulate their behavior to remain below presumptive thresholds, while standardized proxies may misclassify efficient firms as evaders or unfairly burden struggling businesses (Yitzhaki, 2007).

Although the theoretical underpinnings of presumptive taxation are well documented (Engen and Skinner, 1996), empirical evidence on its real-world impacts remains limited—particularly in advanced economies (Ferrara, Bucci and Campagna, 2023). The literature is disproportionately focused on developing countries, despite the adoption of such regimes in high-income contexts. This study addresses these empirical and geographical gaps by examining the perceived effects of Greece’s newly implemented presumptive taxation scheme on self-employed individuals and small businesses.

Using data from a nationally representative survey of 369 entrepreneurs, this study evaluates perceptions of the regime’s fairness, effectiveness, and necessity. Results indicate widespread dissatisfaction: most respondents view the regime as punitive and detached from actual business conditions. Freelancers report acute financial pressure and criticize the regime’s inability to account for income volatility and sectoral disparities. A notable divergence emerges between newly established and long-standing firms, with the former expressing heightened concern over enforcement intensity and long-term viability. Crucially, the regime does not appear to foster voluntary compliance—undermining one of its primary policy rationales.

These findings challenge the efficacy of uniform presumptive approaches in complex and heterogeneous taxpayer environments. They highlight the need for a more nuanced, evidence-based design that balances administrative simplicity with fairness and responsiveness. Recalibrating presumptive systems to reflect actual earning capacity, sectoral diversity, and operational constraints is essential to restoring taxpayer trust, improving compliance outcomes, and reinforcing the

legitimacy of fiscal institutions—especially among economically vulnerable segments of the self-employed.

**Keywords:** *presumptive taxation, freelancers, minimum tax presumptions*

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## **Tax systems procedures' complexity and simplification through the implementation of digitization practices**

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### **Abstract**

Tax complexity is a global phenomenon, which in recent decades has caused concern to governments and businesses. The multidimensional nature and the increasing level of complexity of tax systems seem to be an obstacle to the economic prosperity of countries and lead to undesirable tax planning and an obstruction to both efficiency and profit. Tax system Complexity has not received a widely accepted definition in literature. It is observed, however, that tax legislation; dysfunctional procedures of administrative authorities and tax non-compliance of both citizens and economic entities are common characteristics of most states and considered the driving factors of complexity. These specific factors trigger tax complexity in Greece, since the aforementioned tax system is a typical example of a complex tax system. The purpose of this paper is to formulate in a first stage the characteristics and driving forces of tax complexity and also to seek the usefulness of information systems and digitalization in addressing the phenomenon. The research is based on data from 207 questionnaires on perceived tax complexity from the perspective of taxpayers. Specifically, this paper analyzed how tax complexity is affected by the assessment of the tax system, the necessity of digitalized taxation and tax simplification, as well as the benefits of upgrading information, and the phenomenon of multi-legislative legislation for tax procedures. According to the results, taxpayers point to the issue of tax law ambiguity as the determining factor in tax complexity problems. Although respondents consider the use of upgraded information systems and digitalized taxation as factors that will help resolve previous issues related to time, cost and disclosure, the practices of tax administration offices demonstrate a slower response rate in terms of changes in efficiency and simplification.

**Keywords:** *Tax System, Tax Complexity, Information Systems, Digitized Taxation, Tax Simplification*

## 1. Introduction

Taxes constitute a very broad and complex network of contributions from citizens to the state. In a democratic society, each citizen is responsible for paying a series of different taxes, depending on their activity, income and property. Given the complex structure of each individual tax, as well as the fact that tax rules, rates, exemptions and exemptions are subject to change depending on the income needs of the state, it is clear that deciphering and analyzing the tax system is an extremely difficult task.

A tax system is expected to serve many different purposes. According to Piper J. (2013) three of its main roles are to increase state revenues, to distribute resources and wealth, and to regulate the behavior of taxpayers. It is widely accepted that tax systems can become extremely complex and this has an impact on all taxpayers, whether individuals or legal entities (Budak et al., 2016). The complexity of tax laws and the continuous amendments to tax acts lead to uncertainty for taxpayers, who find it difficult to determine the income and time period for which they are taxed, the tax bracket to which they fall, as well as how to complete their tax return (Bronchi C., 2001). A complex tax system may also distract businesses from their main goal, which is profit, but also burden them with additional difficulties (Burman & Gale, 2001). Therefore, complexity is presented as a discouraging factor for taxpayers' participation in the formal economy, thus reducing their tax compliance.

The totality of taxes levied by a country makes up its tax system. There are significant differences between the tax systems of different countries, as each system is shaped by the unique economic, social and political conditions of each country. In developed economies, direct taxes are usually the most common type of tax, while in developing economies, indirect taxes are the most common. This is due to the fact that in developed economies, incomes are higher, tax administration is more organized, the accounting organization of economic units is more advanced and taxpayers are less likely to evade taxes. As a result, income taxation is more effective. In contrast, income inequality is higher in developing economies, tax services are less organized and there is a greater tendency for tax evasion by economic units. As a result, income tax revenues are low and these countries rely mainly on indirect taxes (Georgakopoulos, 2012).

The Greek tax system includes a wide range of taxes, including those based on income, wealth and expenditure. Most taxes are levied for the benefit of the state, some are levied for the benefit of social security institutions and others for the benefit of local governments. Greece's tax revenues from 2008 to 2020 were mainly derived from indirect taxes and social solidarity contributions and less from direct taxes. Compared to the rest of the European Union (EU-27) countries, Greece's tax revenues are mainly based on indirect taxes, unlike the rest of the countries, which rely on average on direct tax revenues.

Although the Member States of the European Union (EU) are required to harmonize their value added tax (VAT) rates, significant differences still exist between EU countries (Enache, C., 2023). The basic VAT rate in Greece is 24% and corresponds to the highest tax rates among European countries. According to research data (Kefim & Taxfoundation, 2022), the personal income tax rate on dividends in Greece (5%) is significantly lower than the average rate across OECD countries (24.2%). Similarly, the corporate income tax rate in Greece (22%) is lower than the average rate across OECD countries (23.6%). Finally, Greece's Controlled Foreign Company regulations are relatively modest and only concern passive income. The above features are among the strengths of the Greek tax system. On the contrary, as we mentioned, the high tax rate (24%) in our country combined with the limited tax base constitute its main disadvantage. Rapanos and Kaplanoglou (2014) in a case study of the Greek economy concluded that the fundamental weaknesses of the Greek tax system are mainly structural and related to the inefficiency of tax administration, the frequent changes to the tax code and the complexity of tax legislation, factors that we will analyze in the following chapters.

With the spread of technology in recent years, information systems have become an integral part of the tax process. The use of e-government systems is vital for the efficiency and effectiveness of public administrations and, by extension, the tax system. In today's digital world, the transition to a digitalized tax system is increasingly important with the aim of eliminating manual and time-consuming procedures, such as bureaucracy, improving the transparency and accuracy of tax returns and reducing the likelihood of human errors and fraud.

Through this theoretical framework, the research interest was created to study taxpayers' perceptions of the complexity of the tax system and how this is affected by the usefulness of information systems, digitalization and the necessity to simplify tax procedures.

## **2. Literature Review**

### **2.1 Tax System Complexity**

According to the literature, there is no commonly accepted definition of tax complexity. Many different interpretations of the concept have been observed by various scholars, as its acceptance depends on the perception, status of individuals, their expectations and their research interest (Tran-Nam B. & Evans C., 2014).

Tran-Nam B. & Evans C. (2014) attempted to classify tax complexity into four categories. This distinction was made depending on the stage of operation of the tax system, in which the complexity is located. They argued that the complexity of the tax system can be divided into four types: a) political, b) legislative, c) administrative and d) compliance complexity. They developed an index to calculate the overall complexity of a tax system at a given point in time and facilitate future comparisons of tax systems' complexity between countries, but also to assess the changing level of complexity of a country's tax system over time. They argued that excessive complexity has a negative impact on economic growth. Also, complexity seems to increase exponentially if taxpayers, whether individuals or legal entities, operate in more than one tax jurisdiction (Piper J., 2013).

Hoppe et al. (2019) wanting to capture the multidimensional nature of tax complexity from the perspective of multinational enterprises, tried to create an indicator to measure tax complexity, the Tax Complexity Index (TCI). The main complexity factors arising from the tax code are excessive details and frequent changes in tax legislation. Accordingly, the inconsistency of employees when conducting tax audits and amendments to tax legislation with retroactive application feed complexity in the enactment process. The researchers concluded that the level of tax complexity as a whole differs significantly from country to country. Specifically, countries were observed which, despite having one of the most complex tax systems, their overall level of complexity was considered moderate due to the combination of a high level of complexity in the tax framework with a low level of complexity in the tax code or vice versa. Another conclusion of the research by Hoppe et al. (2019) emphasized that tax complexity is negatively correlated with the governance of a country, which results from the negative correlation of governance with the complexity of the tax framework. Therefore, countries that are strongly governed tend to have less complex tax standards. On the contrary, they found that there is a positive sign in the relationship between tax complexity and the statutory tax rate, as countries with high taxes usually rely on a more complex tax code.

According to Piper J. (2013), the lack of clarity in policy formulation, inconsistency in legislation and dysfunctional bureaucratic procedures constitute the greatest source of complexity. The ambiguity and excessive complexity of a tax system leaves room for errors and non-compliance with the rules.

### 2.1.1 Tax code and Framework Complexity

Complexity affects SMEs to a greater extent (Hoppe et al., 2017). In particular, tax calculation and record keeping seem to be more difficult for smaller companies. In contrast, large companies often face complex tax legislation and are more likely to make errors in their tax returns due to the ambiguity of the law (Lazos, 2016). The main difficulties faced by corporate tax professionals are due to tax calculation, record keeping and the ambiguity of the tax law (Isa, 2014) as they have a lower capacity to respond to complex tax regulations compared to multinational companies (Freudenberg et al., 2012).

Borrego et al. (2016) report that the main factors of tax complexity are due to instability, dispersion of tax laws, time-consuming preparation of accounting information for tax purposes, transitional arrangements and ambiguity of the tax code were considered the five most important causes.

The finding that the tax system is often imposed in a haphazard manner and tax justices is not applied fairly and correctly, due to excessive bureaucracy of the tax system, are reasons that contribute to an increase in the sense of injustice of taxpayers. This leads to a decrease in their voluntary tax compliance (Borrego et al., 2016; Lazos G., 2016).

Another area of tax complexity is the complexity of the tax framework, which results from the characteristics of a tax system, but also from the legislative and administrative procedures of a country. For example, the complexity of transfer pricing regulations is due to their documentation requirements, but also to the difficulty that distinguishes them in terms of their interpretation and clarity. Inconsistencies of tax officials in their decisions and long statutes of limitations contribute to the complexity of tax audits (Hoppe et al., 2019).

Tax and judicial fines, as well as unnecessary bureaucratic procedures of public administration, seem to have a negative impact on the tax system's efficiency (Shahroodi, 2010). On the contrary, the use of information systems and the training of taxpayers and administrative officials are factors that improve the efficiency of the tax system (Karagiorgos et al. 2022).

The additional cost that taxpayers incur for complying with tax requirements beyond their tax obligations is called compliance costs (Sandford et al., 1989). Many studies have concluded that tax complexity leads to an increase in compliance costs. The complexity that characterizes tax systems and tax administrations seems to facilitate corruption in tax authorities and tax non-compliance among taxpayers. Tanzi V. (2017) in an attempt to explore the links that link corruption and tax evasion with increasing complexity concluded that tax complexity in terms of its legislative dimension is a determining factor.

The complexity of the Greek tax code can be easily perceived (Tatsos N., 2001). As the research of Dianeosis (2016) supports, tax complexity is an important reason for the prevalence of tax evasion in our country. Lack of attention in the preparation of tax laws and failure to foresee impacts on the economy and society, the deliberate gaps that are often found in the legislation, resulting in unjustified tax exemptions, encourage tax evasion and misinterpretation of tax legislation (Mavridou A., 2022).

The OECD (2018) observed that there is a large abundance of interpretative circulars from the Tax Administration. Karagiorgos et al. (2022) in their research showed that the main causes of complexity are due to the structure of the legislation, political instability and central planning. Factors such as the inefficiency of public administration and the implementation of tax legislation were identified that lead to even greater complexity.

### 2.1.2 The Cost of Complexity and Tax Compliance

Hamid et al. (2022) in their research examined perceptions of tax awareness, tax education and tax complexity from the perspective of SMEs. According to the results, SME owners perceive tax as a burden that reduces their income and purchasing power. Regarding the level of their tax education, it was shown that although most participants had received tertiary education, their level of tax knowledge was insufficient.

The complexity of the tax system usually causes confusion among taxpayers and leads them to unintentional or intentional non-compliance. This fact, combined with the low level of tax knowledge of taxpayers, may be a cause of inaccuracy in their tax returns (Loo et al., 2008). Saad (2014) showed that taxpayers have insufficient knowledge of the income tax system in terms of its technical aspect and consider the tax system to be inherently complex. Richardson (2006) examined the main determinants that lead to tax evasion. The factors that have a decisive and strongest impact on tax evasion are non-economic in nature. In particular, tax complexity is positively correlated with tax evasion and is its most important factor.

Lois et al. (2019) confirm that factors such as the competence of tax administrators, as well as the fairness of the tax system, have a positive impact on citizens' tax compliance. In particular, the perception of a fair tax system builds trust between citizens and the tax administration and leads to higher levels of voluntary compliance (OECD, 2018; Lois et al., 2019). Papaconstantinou et al. (2013) respectively studied the phenomena of bureaucracy and corruption in the European Union as inhibiting factors of economic growth, consistently leading to complexity.

Also of interest is the study by Vousina G. (2017), which analyzes two important problems that Greece faces in its economy, tax evasion and shadow economy. Specifically, high levels of corruption, lack of tax awareness, the inefficient structure and complexity of the tax system inevitably lead to phenomena of tax evasion and shadow economy. These phenomena in turn lead to an increase in administrative costs and compliance costs (Katsios S., 2006).

The design and evaluation of an ideal tax system are based on three commonly accepted basic criteria, such as simplicity, fairness and efficiency (Lazos G., 2016). According to Jackson & Milliron (1986), a simplified tax system reflects the reduction of tax complexity and is one of the factors that affect tax compliance. Specifically, a simple tax system governed by predictable and clearly formulated rules can lead to an increase in tax compliance (McKerchar, 2002).

### 2.1.3 The Usefulness of Information Systems in Taxation

Information systems play a vital role in the smooth functioning of businesses and other organizations. They allow organizations to interact with their customers and suppliers and remain competitive in the market (Zwass, 2022). Information systems are particularly useful in environments where there is a large volume of data, which must be analyzed accurately. A typical example of such an environment in the public sector is taxation, where information systems collect data from various sources and should be user-friendly, while at the same time they should be reliable (Dečman M. & Klun M., 2017).

To transform the public into an audience of trusted citizens, significant improvements in government performance and evidence that technology is responsible for this improvement will be needed (Economides and Terzis, 2008). In the study by Shahroodi (2010) mentioned in Chapter 2, 80% of tax experts who responded to the survey also recognize the use of information systems as an important factor in enhancing the efficiency of the tax system.

As the nature of government operations changes, continuous investments in training and expertise will be necessary to ensure that civil servants are able to keep up with the demands of new technology (Terpsiadou M. & Economides A., 2009). According to the article by Walker D. (2022) technology

can help solve problems of tax complexity and opacity. According to a study by Prasopoulou E. (2011), the lack of clear political objectives and standardized administrative practices gradually transformed Greek public bodies into large, complex organizations that provide low-value services to citizens.

According to Lazakidou A. (2021), certain goals should be set for the proper utilization of e-government. Cooperation between political and administrative leadership, as well as adequate funding, are necessary elements in order to overcome the aforementioned difficulties and create strong information systems (Rossidis and Belias, 2021). However, overall, Greece has made satisfactory progress in recent years compared to other EU countries, which means that Greece is closing the gap (Rossidis and Belias, 2021). This improvement is not easily perceived by the average citizen, as the demands for more sophisticated and reliable service provision by public bodies have increased rapidly (Kontogeorgis and Varotsis, 2021).

### 3. Methodology and Results

In this specific survey, the final sample consisted of 207 Greek taxpayers. Non-probability sampling, specifically convenience sampling, was chosen as the survey sampling method. The reason for choosing this specific method was easy and quick access to the sample without restrictions. Therefore, the results obtained from the survey cannot be generalized due to the specific choice of sampling technique.

The survey was based on citizens' opinions and perceptions on the issue of tax complexity without distinction as to their familiarity with taxation or whether they possess knowledge of information systems. The first stage of the questionnaire consists of questions aimed at creating the demographic profile of the respondents. The data examined were gender, age, educational level and professional training.

The main part of the questionnaire consists of 34 questions. The answers to the specific questions are based on the 5-point Likert scale. The questionnaire was distributed to respondents online, its completion was voluntary and anonymous. As the completion of this specific tool did not require specialized knowledge regarding taxation and the usefulness of information systems, efforts were made to make the wording of the questions as friendly and simple as possible for the respondents.

The questions study the characteristics of our tax system in general and not the subject of the research itself, which is tax complexity. In particular, the respondents were asked to answer questions regarding the effectiveness, fairness, transparency, simplicity of our country's tax system and the support for investment and entrepreneurship.

Some questions aim to record the views of taxpayers regarding fairness, reward and the benefits of tax awareness. Then, a group of questions aimed to explore citizens' perceptions of the impact of information systems on resolving tax complexity, their degree of familiarity and facilitation with the use of information systems in taxation, the extent to which they believe that information systems help public administration in serving citizens and whether they believe that they should be redesigned to be more user-friendly.

Finally, three questions explore the way in which citizens perceive the benefits of resolving tax complexity through the simplification of tax procedures. For this reason, questions were created regarding the extent to which they believe that a simplified tax system increases state revenues and helps to form a higher tax conscience.

The IBM SPSS statistical software package was used to process and analyze the data obtained from the research tool. Specifically, we proceeded with descriptive statistics for the demographic

characteristics of the sample, as well as with joint factor analysis in order to optimally present the results and the relationships between the variables.

**Table 1:** *Descriptive Statistics*

| Gender     |                         |           |         |               |                    |
|------------|-------------------------|-----------|---------|---------------|--------------------|
|            |                         | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid      | Ανδρας                  | 86        | 41,5    | 41,5          | 41,5               |
|            | Γυναίκα                 | 121       | 58,5    | 58,5          | 100,0              |
|            | Total                   | 207       | 100,0   | 100,0         |                    |
| Age        |                         |           |         |               |                    |
|            |                         | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid      | 18-24                   | 27        | 13,0    | 13,0          | 13,0               |
|            | 25-34                   | 93        | 44,9    | 44,9          | 58,0               |
|            | 35-45                   | 47        | 22,7    | 22,7          | 80,7               |
|            | 46-65                   | 37        | 17,9    | 17,9          | 98,6               |
|            | >65                     | 3         | 1,4     | 1,4           | 100,0              |
|            | Total                   | 207       | 100,0   | 100,0         |                    |
| Occupation |                         |           |         |               |                    |
|            |                         | Frequency | Percent | Valid Percent | Cumulative Percent |
| Valid      | Student                 | 11        | 5,3     | 5,3           | 5,3                |
|            | Private Sector Employee | 101       | 48,8    | 48,8          | 54,1               |
|            | Public Sector Employee  | 24        | 11,6    | 11,6          | 65,7               |
|            | Free Lancer             | 39        | 18,8    | 18,8          | 84,5               |
|            | Pension                 | 9         | 4,3     | 4,3           | 88,9               |
|            | Unemployed              | 22        | 10,6    | 10,6          | 99,5               |
|            | Other                   | 1         | ,5      | ,5            | 100,0              |
|            | Total                   | 207       | 100,0   | 100,0         |                    |

The first part of the survey concerns general questions (1-4) regarding the demographic characteristics of the sample. Our research sample consists of 207 taxpayers. The 1st question concerns the gender of the respondents and the results are presented in the table below. According to the data in Table 1, of the 207 participants, 41.5% correspond to men, while 58.5% correspond to women. As we can see, the number of women who participated in the survey exceeds that of men. According to the results, the largest percentage of respondents (44.9%) is found in the age group of 25-34 years. This is followed by the age group of 35-45 years with a percentage of 22.7% and the age group of 46-65 years with a percentage of 17.9%. The youngest ages (18-24 years old), as well as participants over 65 years old, had the lowest participation rates, 13% and 1.4% respectively. However, it is positive that there were participations from all age groups. 48.8% of the sample work as Private Employees, 18.8% as Freelancers and 11.6% as Public Employees. This is followed by the 10.6% of the sample, who did not have any professional employment during their participation in the survey. Students and Pensioners have a low participation rate with only 5.3% and 4.3% respectively. Of the participants, there was 1 participation that did not correspond to any of the Employment Status options.

#### 4. Discussion and Conclusions

Initially, the determining factors that emerged from our research include the assessment of the tax system by taxpayers, the necessity of digitalized taxation, the nature of tax complexity, and the advantages of information upgrading, the necessity of tax simplification and the unclear tax polytheism.

According to the results of the research, the way in which taxpayers perceive tax complexity and the problems that arise from it affects their overall impression of the overall capacity of the tax system. Specifically, the more the problems created by tax complexity intensify, the less positive the citizens' impression of the overall performance of our tax system decreases. On the contrary, the more citizens form a good impression and positively evaluate our tax system, the more the problems that lead to its complexity seem to decrease.

Tax compliance has been found, according to the literature, to be a key factor that influences and is simultaneously affected by tax complexity. Although the sample was asked about tax awareness issues related to tax complexity, the use of information systems and the digitalization of processes, it did not ultimately emerge as a factor examined in the statistical data analysis. In conclusion, the findings of this survey are based on citizens' perceptions of the complexity of the Greek tax system and the usefulness of information systems at a given point in time. However, the globalization of markets and technological progress have created a new, more complex economic system that affects the way businesses interact with each other and the way tax regulations and other policies are implemented globally. The complexity of this new economic system was not included in our survey.

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# **The duty of corporate governance compliance under Greek and European law: from formal requirements to strategic responsibility**

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## **Abstract**

Corporate governance has evolved from a voluntary framework into a legally binding regime across the European Union, reflecting the increasing emphasis on transparency, sustainability, and accountability. This paper explores the legal obligations surrounding corporate governance compliance under both EU and Greek law, examining the transformation driven by key directives such as the Shareholders Rights Directive II and the Corporate Sustainability Reporting Directive. In the Greek context, Law 4706/2020 has established a robust governance framework for listed companies, harmonizing national law with European standards. By analyzing the interplay between compliance duties, board responsibilities, enforcement mechanisms, and emerging ESG obligations, this study highlights the shift from formal compliance to a culture of responsible corporate stewardship. The paper concludes with a critical assessment of legal and practical challenges and proposes directions for future regulatory and corporate practice.

**Keywords:** *European Union, legislation, jurisprudence, company law, competition, enterprises.*

## **Scientific collaboration networks among researchers and social network analysis: the case of the School of Economics and Business Administration of International Hellenic University**

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### **Abstract**

Scientific collaboration networks have long been a subject of interest across numerous academic disciplines. In this paper, we examine the scientific collaboration networks created among researchers in all five departments of the School of Economics and Business Administration of International Hellenic University. We study faculty members who are lecturers, assistant professors, associate professors, and professors. We draw from Google Scholar to collect their publications (articles, conference papers, book chapters) from 2020-2024, and we use NodeXL Pro to create and visualize their collaboration networks. This paper attempts to answer the following research questions: 1) what are the characteristics (metrics) of the networks created among the researchers in the School of Economics and Business Administration, 2) what are the characteristics of the vertices/authors in the network, 3) what are the most important vertices/authors based on their betweenness centrality, closeness centrality, eigenvector centrality, and clustering coefficient, and 4) is there any discrepancy between male and female authors in terms of scientific production. The study reveals 767 vertices (authors) and 4808 total edges, 3 self-loops, 10 connected components, and the density of the graph is low. Overall, we notice local collaboration, a specific central component, and a wide range in centrality and collaboration metrics. Vertices/authors that rank high in the network metrics play the role of bridge or interact more with the most influential authors. Of 767 authors, 181 are lecturers, assistant professors, associate professors, and professors, while the rest are external researchers, PhD students or other academic staff. Authors from the International Hellenic University seem to collaborate more often together (local collaboration) than with authors from various universities across Greece. Regarding the last research question, there seems to be a gender disparity, with male authors being more active, and central than female ones. More data from more universities would provide useful insight into this finding. Building on previous studies, this research extends the investigation by looking into collaboration networks at various levels. The broader objective of the research is to develop a Collaboration Index, which could be a potential resource for the H.Q.A.A. (Hellenic Quality Assurance and Accreditation Agency) and other quality assurance organizations at the EU level.

**Keywords:** *scientific collaboration networks, social networking analysis, School of Economics and Business Administration, International Hellenic University*

## 1. Introduction

Social Networking Analysis (SNA) has been applied in many disciplines, including economic sciences, medicine, and social sciences. However, there is no specific definition of what SNA is. Buch-Hansen (2013) described SNA as a theory, a strategy, an approach, and as a set of techniques. Marin & Wellman (2011) defined it as a “paradigm.” The main objective of Social Networking Analysis is to examine the connections among individuals, the framework of these connections, and how they affect social behaviors and attitudes (Prell, 2011). As noted by Freeman (2004), social structure emerges from the relationship patterns that individuals create through their interactions. Consequently, the idea of interaction among individuals holds significant importance (Marin & Wellman, 2011; Wasserman & Faust, 1994), and all its facets contribute to changes in both individuals and the overall network (Freeman, 2004).

SNA examines the collaborative networks created through the interaction among and across different entities (individuals or organizations). Recently, there has been an increased focus on the study of collaborative networks and the traits they exhibit at both the micro and macro levels (Camarinha-Matos & Afsarmanesh, 2004). SNA has gained increased traction lately driven by the vast amount of data available and the computational techniques that can analyze them (Di Bella et al., 2021). Collaboration networks analyze the structure, behavior, and dynamics of individuals working together to achieve a shared objective. They consist of various independent entities that aim to achieve common objectives although individually they differ from one another to a smaller or larger extent. Collaborative networks permeate social and business life so much so that researchers have highlighted the need for an independent scientific field with its principles, practices, and a specialized academic community. Researchers have even gone so far as to argue that the sustainability of companies relies on them being part of integrated collaborative networks (Hwang et al., 2008). Similar observations have been made in various other fields, such as the public sector (Mischen, 2015), educational institutions (Noran, 2013), and even the tourism industry (Larson & Gyimóthy, 2013).

Similar collaboration networks have also been identified among educational institutions (Di Bella et al., 2021) and across multiple scientific fields (Henriksen, 2016; Kuld & O’Hagan, 2018). The study of scientific collaborative networks has lately known a heightened, most likely driven by an increasing trend towards examining cooperative efforts in general (Di Bella, E. et al., 2021). In our research, following Newman, M. E. J. (2001), we consider that scientific collaboration arises from the co-authoring of a scientific article by two or more co-authors. Authors are the nodes in the network and the edges represent the patterns of collaboration. Connecting two nodes requires that these researchers have worked together in at least one article. Besides increasing the quality and quantity of scientific output (De Stefano et al., 2010), the goal of collaboration, often interdisciplinary, is to approach scientific domains from other viewing angles that could lead to their better understanding and to the birth of new ideas.

The present paper aims to examine the scientific collaboration networks created among researchers in all five departments of the School of Economics and Business Administration of International Hellenic University. We study faculty members who are lecturers, assistant professors, associate professors, and professors. We draw from Google Scholar to collect their publications (articles, conference papers, book chapters) from 2020-2024, and we use NodeXL Pro to create and visualize their collaboration networks.

We attempt to answer the following research questions:

- 1) What are the characteristics (metrics) of the networks created among the researchers in the School of Economics and Business Administration?
- 2) What are the characteristics of the vertices/authors in the network?

3) What are the most important vertices/authors based on their betweenness centrality, closeness centrality, eigenvector centrality, and clustering coefficient?

4) Is there any discrepancy between male and female authors in terms of scientific production?

The paper is organized as follows. In the second section, we analyze the methodology adopted, in the third section we go over the data collection process, in the fourth section we present the results, and in the fifth section, we discuss our findings and their implications, list possible limitations as well as offer suggestions for further research.

## 2. Methodology

We examine our research questions using Social Networking Analysis because our research focuses on the relationships that develop within a network and the structure that arises from these interactions. To graphically visualize our findings and explore the graph metrics, we utilize NodeXL Pro which enables users to import, manage, and create networks (Smith et al., 2010). Each network comprises nodes, authors in our case, and edges between those nodes, instances of co-authorship in our case. The relationships that develop between the nodes can vary in nature; they may be bi-directional or mono-directional, have weight (weighted graph) assigned to them or not (unweighted graph) (Wasserman & Faust, 1994).

This study focuses on the collaboration networks formed among faculty members as part of their joint efforts to publish scientific papers. The analysis of these collaborative networks will reveal important insights regarding the individual nodes and the kind of relationships that develop between them. We specifically examine the most significant collaboration networks and the most influential nodes by checking the graph metrics of the corresponding nodes. How influential a node is, is determined here by the frequency of collaboration with other nodes and by the number of published papers resulting from each collaboration; we use various network metrics, including Degree centrality (number of direct connections), Closeness centrality (how close a node is to others), Betweenness centrality (role as a bridge between nodes), Eigenvector centrality (influence based on connections to other influential nodes), and PageRank (ranking based on link importance).

## 3. Data collection process

The present paper aims to examine the scientific collaboration networks created among researchers in all five departments of the School of Economics and Business Administration of International Hellenic University. We study faculty members who are lecturers, assistant professors, associate professors, and professors. We draw from Google Scholar to collect their publications from 2020-2024 and limit ourselves to articles, conference papers, and book chapters.

## 4. Results

Regarding the first research question, the study reveals 767 vertices (authors) and 4808 total edges, 3 self-loops, 10 connected components, and the density of the graph is low. We find 22 groups by connected component. Overall, we notice local collaboration, a specific central component, and a wide range in centrality and collaboration metrics. Vertices/authors that rank high in the network metrics play the role of bridge or interact more with the most influential authors. See *Figure 1* for the visualization of the whole graph.

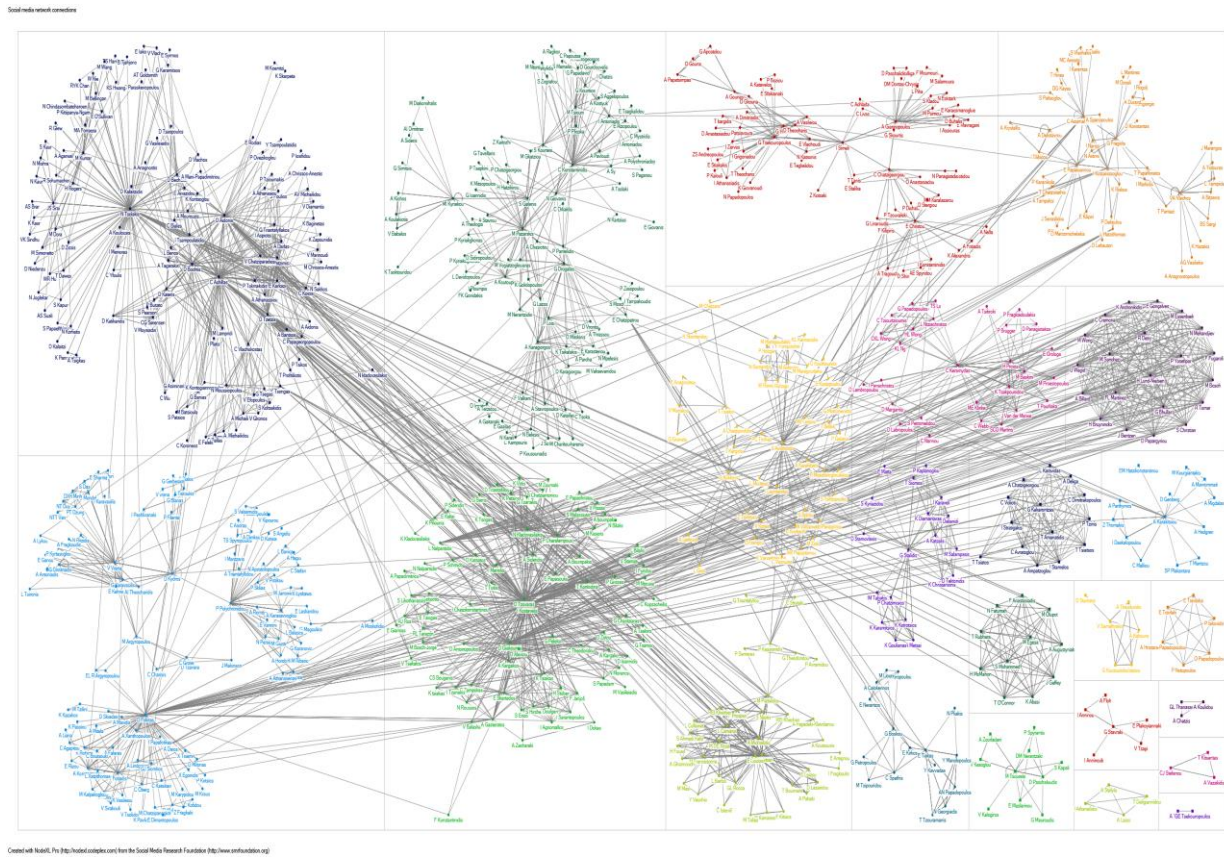


**Figure 1:** *The complete Collaboration network*

Regarding the second research question, we find that of 767 authors, 2 are lecturers, 51 assistant professors, 49 associate professors, and 79 professors, while the rest are external researchers, PhD students, or other academic staff. See *Figure 2* for a graphical distribution of the academic ranks within our sample. Notice that we have omitted the authors from the pie chart that are not in one of the ranks listed above to reduce noise in the visual representation. Authors from the International Hellenic University seem to collaborate more often together (local collaboration) than with authors from various universities across Greece.

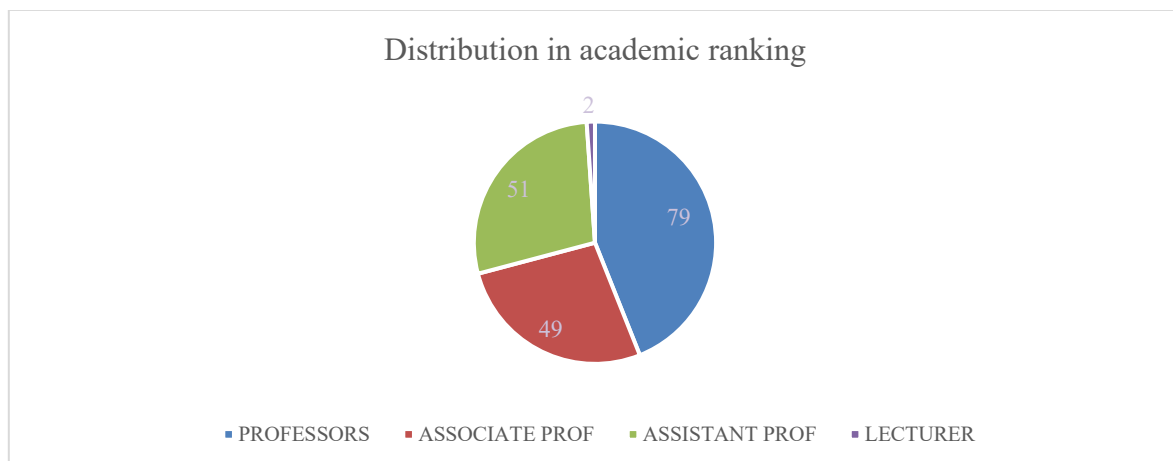


**Figure 2:** *Distribution in academic ranking*

Regarding the distribution in Greek Universities see *Table 1* below. As expected, and due to how the starting point of data collection is the International Hellenic University, most researchers belong to that institution. The “Other” category encompasses cases like authors that do not belong to an academic institution, or belong to a foreign one, or people who would not be generally considered researchers.

**Table 1:** *Percentage of Institutions*

| <b>Institution</b>                                         | <b>Percentage</b> |
|------------------------------------------------------------|-------------------|
| Other                                                      | 76,40%            |
| International Hellenic University                          | 10,43%            |
| Aristotle University of Thessaloniki                       | 4,04%             |
| University of Macedonia                                    | 1,83%             |
| Democritus University of Thrace                            | 1,69%             |
| University of Thessaly                                     | 0,78%             |
| University of Patras                                       | 0,65%             |
| University of Piraeus                                      | 0,65%             |
| Ionian University                                          | 0,52%             |
| University of Western Macedonia                            | 0,52%             |
| University of Peloponnese                                  | 0,39%             |
| Agricultural University of Athens                          | 0,39%             |
| Hellenic Mediterranean University                          | 0,26%             |
| University of Ioannina                                     | 0,26%             |
| Technical University of Crete                              | 0,26%             |
| Harokopio University                                       | 0,26%             |
| Hellenic Open University                                   | 0,13%             |
| School of Pedagogical and Technological Education (ASPETE) | 0,13%             |
| National and Kapodistrian University of Athens             | 0,13%             |
| Athens University of Economics and Business (AUEB)         | 0,13%             |
| University of the Aegean                                   | 0,13%             |
| Total                                                      | 100%              |

The rest of the universities that appear here arise from the collaboration of these staff members with researchers that are permanent staff members in other Greek universities. The distribution by university is available, in absolute numbers, on the pie chart in Figure 3 below. The “other” category is not included in the following figure because it would obscure the graph due to its disproportionately larger percentage.

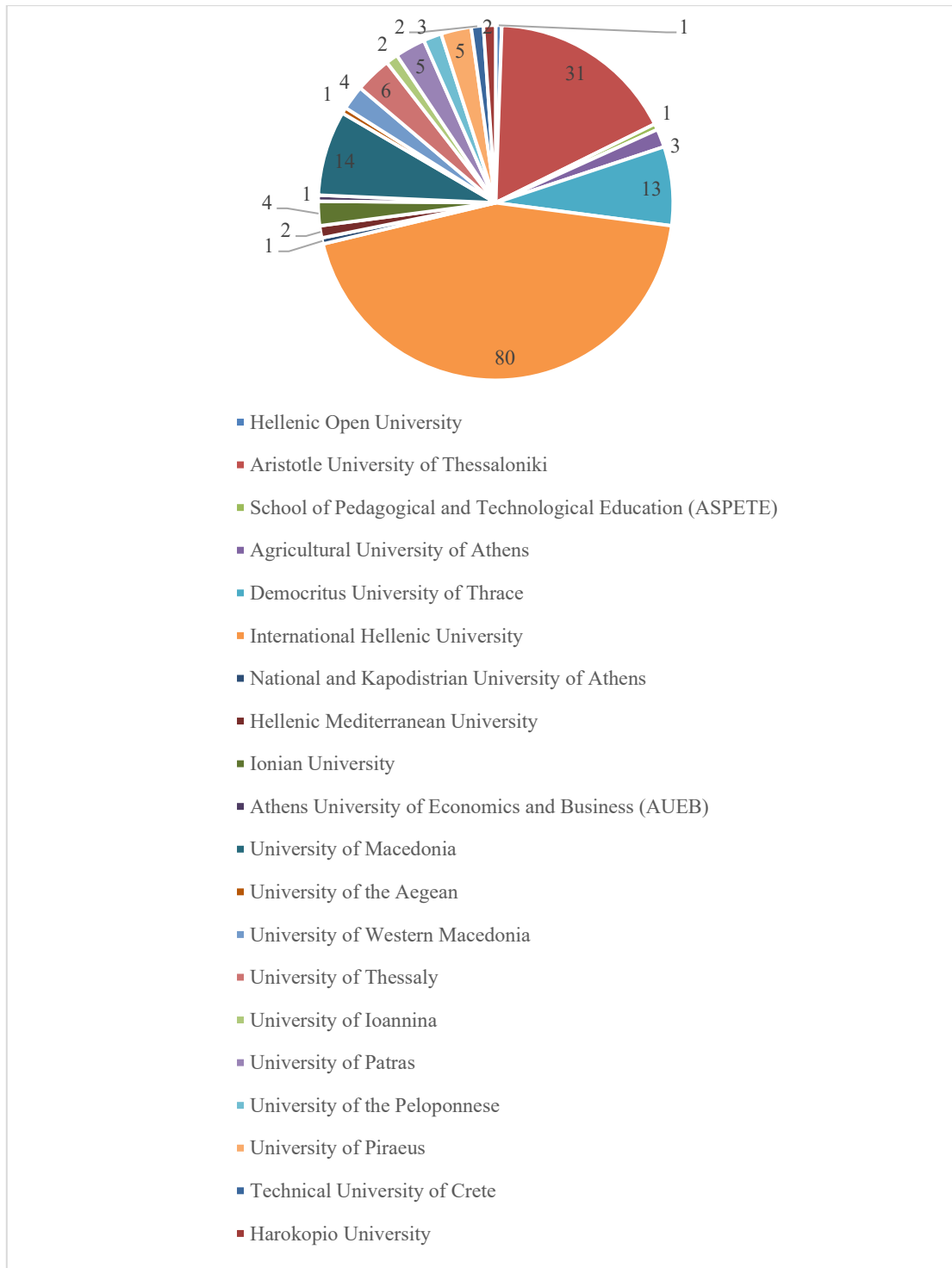


**Figure 3:** *Percentile distribution of academic staff across Greek Universities*

Regarding the third research question, we identify the 20 most prominent researchers based on betweenness centrality, closeness centrality, and eigenvector centrality.

**Table 2:** Author's ranking based on their betweenness centrality

| Vertex           | Betweenness Centrality |
|------------------|------------------------|
| D Folinas        | 100672,891             |
| S Avdimiotis     | 48906,368              |
| I Kotzaivazoglou | 46527,920              |
| N Tsolakis       | 41653,730              |
| C Achilles       | 40583,762              |
| D Kydros         | 39918,261              |
| P Polychronidou  | 38900,346              |
| P Kassianidis    | 33395,682              |
| M Partalidou     | 33268,694              |
| M Argyropoulou   | 32753,582              |
| L Hatzithomas    | 28319,984              |
| D Aidonis        | 27787,957              |
| C Assimakopoulos | 26661,736              |
| M Pazarskis      | 26638,108              |
| G Drogas         | 26140,062              |
| E Papaioannou    | 25157,305              |
| I Kostavelis     | 21902,720              |
| D Tzovaras       | 21109,620              |
| D Theocharis     | 20091,761              |

**Table 3:** Author's ranking based on their closeness centrality

| Vertex             | Closeness Centrality |
|--------------------|----------------------|
| D Folinas          | 0,279                |
| I Kotzaivazoglou   | 0,259                |
| C Achilles         | 0,256                |
| D Kydros           | 0,256                |
| M Argyropoulou     | 0,255                |
| L Hatzithomas      | 0,255                |
| D Aidonis          | 0,254                |
| V Vrana            | 0,244                |
| A Gasteratos       | 0,244                |
| N Tsolakis         | 0,242                |
| D Tzavara          | 0,238                |
| C Grose            | 0,238                |
| P Polychronidou    | 0,238                |
| T Fotiadis         | 0,236                |
| A Konstantoglou    | 0,235                |
| I Kostavelis       | 0,232                |
| D Tzovaras         | 0,231                |
| C Assimakopoulos   | 0,230                |
| A Chrissos-Anestis | 0,229                |

**Table 4:** Author's ranking based on their eigenvector centrality

| Vertex       | Eigenvector Centrality |
|--------------|------------------------|
| I Kostavelis | 0,295                  |
| D Tzovaras   | 0,293                  |

|                |       |
|----------------|-------|
| D Giakoumis    | 0,246 |
| L Nalpantidis  | 0,172 |
| R Detry        | 0,165 |
| H Bruyninckx   | 0,165 |
| A Billard      | 0,165 |
| S Christian    | 0,165 |
| M Bosch        | 0,165 |
| K Andronikidis | 0,165 |
| H Lund-Nielsen | 0,165 |
| P Yosefipor    | 0,165 |
| U Wagid        | 0,165 |
| R Tomar        | 0,165 |
| FL Martinez    | 0,165 |
| F Fugaroli     | 0,165 |
| D Papargyriou  | 0,165 |
| N Mehandjiev   | 0,165 |
| G Bhullar      | 0,165 |

Regarding the last research question, we find that male authors are more active and central than female ones. 498 of the researchers are male and 269 are female. Based on our limited sample, there seems to be a disproportionate distribution, meaning that the academic community remains male-dominated. More data is necessary to find out whether this disparity is real or only owes to the narrow scope of this research.

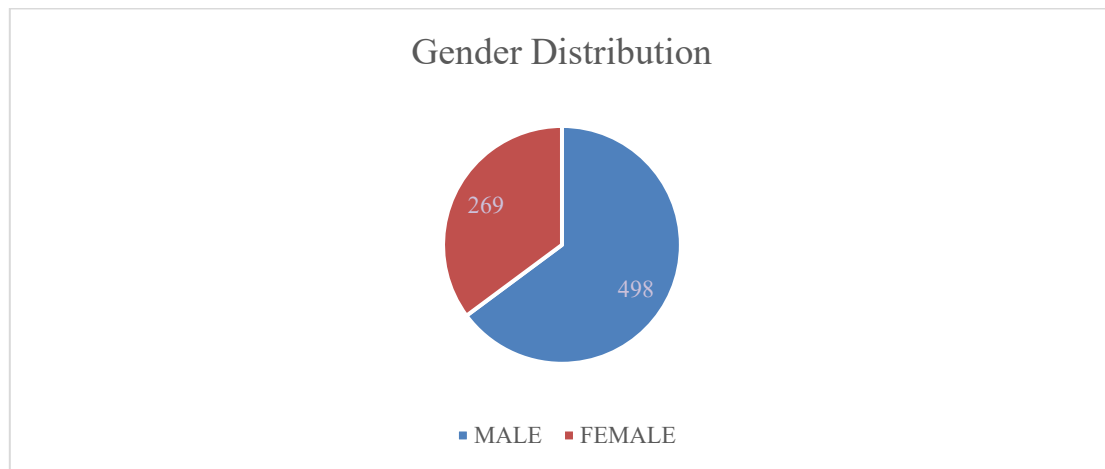


**Figure 4:** *Gender distribution*

## 5. Contribution to Network Analysis Science, implications for the future, research limitations

Our research broadens the current understanding of collaboration networks, focusing on scientific partnerships and the networks established by university faculty members in Greece. Not much research has been conducted in the field of scientific collaboration networks and examining a specific country is even less pronounced with the study of Di Bella et al. (2021) possibly being the only comparable research. We will investigate scientific collaboration networks in Greece for the very first time, beginning from all five departments of the School of Economics and Business Administration of International Hellenic University, and aiming to study all professors and their co-authorship networks in recent years in Greece.

The key objective is to develop a Collaboration Index: a metric designed to help rank Greek universities, that will be available for the HQA (Hellenic Quality Assurance Agency) and broader uses (e.g., assessments at the EU level). A systematic analysis of the collaboration networks on a country basis (Greece in our case) could serve as a model of academic productivity at different institutional levels.

This study has certain limitations. The main consideration is the breadth and depth of the data: we only study one faculty, for a limited amount of time which could be a hindering factor in making generalizations based on this data. Another constraint is the reliance on Google Scholar which could introduce platform-specific limitations like citation accuracy or the existence of duplicate entries. To the extent possible, we tried to ameliorate these issues. Future research could build on our study and extend the timeframe of the examination, include more databases with citation information, and consider more faculties.

## 6. Conclusions

This research examines scientific collaboration networks in academic institutions, using the School of Economics and Business Administration at the International Hellenic University as a case study. By examining co-authorship data from 2020 to 2024 and utilizing Social Network Analysis with NodeXL Pro, the research uncovers essential information about the interaction of faculty members from the International Hellenic University with their colleagues. The results indicate that most collaborations occur locally, with certain individuals being pivotal nodes (based on network metrics) in linking the network. Also, we noticed a disparity between male and female authors with male authors being more active, and central although more data are required to accurately check this. Although this study is temporally limited and only focuses on one faculty, it lays the groundwork for establishing a Collaboration Index as a practical tool for ranking institutions.

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## **The role of packaging in supply chain management and in Gen Z purchase behavior**

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### **Abstract**

Packaging is no longer a passive component but an integral part of supply chain operations, influencing inventory efficiency, product traceability, waste reduction as well as reverse logistics. Moreover, packaging characteristics significantly influence consumers' purchase decisions and behavior and therefore play an important role in marketing strategy. In the present study and through a literature review, the influence of packaging characteristics on purchase decisions and behavior is highlighted and consumer's attitude toward sustainable packaging is explored. From the analysis of previous relevant studies, it was realized that there is a lack in research focusing on consumers belonging to Gen Z, which, according to the literature, is the largest and most powerful consumer generation, expressing intense sustainability concerns and therefore affecting packaging and marketing decisions made by companies. To address the above issues, a quantitative research study was conducted on a sample of 207 Greek consumers, aged 18-27, with the use of an online questionnaire. Findings demonstrate that packaging elements such as sustainability, innovation and design have the most significant impact on Gen Z consumers' purchase behavior. Moreover, respondents stated that they are likely to purchase products influenced by sustainable packaging characteristics and they will consider switching to a brand that offers such products. The implications of this research can inform marketing and logistics decisions related to packaging design, cost-efficiency and sustainable material selection. By linking Gen Z consumer behavior with operational decision-making, this study contributes to the broader understanding of how demand-side preferences shape upstream activities in production and distribution systems, as well as in marketing strategy formulation.

**Keywords:** *Packaging, Supply Chain Management, Purchase Behavior, Gen Z, Research*

## 1. Introduction

Packaging is not only important for the protection of products and the facilitation of supply operations, but it is also considered as a valuable marketing tool that influences consumer perceptions and purchase decisions (Alhamdi, 2020).

In previous years, studies (Ahmed et al., 2014; Tinonetsana et al., 2017; Waheed et al, 2018) have mainly focused on the physical attributes and on the aesthetics-design elements of packaging, such as color, images, material, fonts, wrapper design etc. However, Nanos et al. (2025) argue that there is a lack of relevant studies, especially in Greek context, that will examine not only the physical-design elements of packaging, but also the packaging innovations and information provided. In addition, and due to the increasing environmental concerns, there is a rise in studies analyzing the role of packaging sustainability on shaping purchase behavior (van Bussel et al., 2022), especially in younger generations which are the future of our planet (Tyson et al., 2021) and are more likely to be influenced by sustainable packaging (Statista, 2025).

As far as the studies about packaging and sustainability are concerned, Chirilli et al. (2022) explored Italian consumers' perceptions of environmentally sustainable issues related to food packaging. The results of their survey revealed that gender, age, and education level significantly affect consumer awareness, behavior and expectations regarding food packaging. Also, participants expressed a strong desire for detailed information on food packaging regarding the materials used, recycling options and environmental impacts. Finally, there is a notable gap between the positive attitude towards sustainability and the actual purchase behavior, suggesting that increased awareness and better communication about sustainable practices could help close this gap, emphasizing the need for improved communication strategies to engage consumers effectively.

Herrmann et al. (2022) examined German consumers' willingness to pay for products with different types of packaging, including paper, recyclable plastic and bioplastic. Their results indicate that consumers seem uncertain about which packaging materials (and products) are sustainable. Consumers ranked unpackaged products as the most sustainable ones, followed by products with paper and recycled plastic packaging, while bioplastics were perceived as not sustainable, unnecessary and greenwashing. Finally, the research underlines the importance of providing consumers with clear and accessible information on the sustainability of packaging materials to help them make their choices.

In their research, Duarte et al. (2024) found that willingness to pay and attitude towards sustainable packaging are strongly and positively related to purchase intention of products with sustainable packaging. In their suggestions for further research, the authors propose the implementation of studies on larger sample sizes and more diverse demographic groups, in order to enhance the robustness of the findings and ensure that results can be generalized across different consumer populations.

Finally, Nanos et al. (2025) indicate that packaging elements affect consumer's perceptions about the quality of a product and influence their purchase intentions. However, packaging material (plastic, glass, paper etc.) and packaging innovations (such as reusable, eco-friendly, durable and easy to open packaging) do not play a decisive role in Greek consumers' purchase decisions compared to other countries, where sustainability issues get more attention and green consumer buying behavior is more developed.

Considering all the above, the aim of this paper is to explore the role of packaging in the purchase behavior of Generation Z consumers (people born between 1997 and 2012, according to Dimock, 2019), which, according to the literature, is the largest and most powerful consumer generation, expressing intense sustainability concerns and therefore affecting packaging and marketing decisions made by companies (Tyson et al., 2021). This argument is also supported by Statista (2025), which indicates that over 70% of young consumers worldwide have chosen a product based on its

sustainable packaging in 2023. Moreover, young consumers hold the largest percentage of the sustainable food and beverage market share in the U.S. and for Gen Z consumers this market is estimated to increase further in the upcoming years (Statista, 2025).

The objectives of this study are to: a) explore GenZ consumers' perceptions of packaging and their role in formulating purchase behavior, b) examine the various elements of packaging (including sustainability) that influence consumers' intention to buy a product and c) measure the influence of packaging on consumers' purchase intentions.

## 2. Methodology

To explore the above-mentioned issues and achieve the objectives of the study, the theoretical framework of Waheed et al. (2018) was adopted, extended with the dimension of innovation, as studied in Nanos et al. (2025) and the dimension of sustainability, as proposed by Duarte et al. (2024). More specifically, consumers' purchase intentions are influenced by packaging color, packaging material, packaging design and printed information (Waheed et al., 2018), packaging innovation (Nanos et al., 2023) and sustainability features (Duarte et al., 2024).

The study focused on Generation Z, and more specifically in Greek consumers aged between 18 and 27 years old. All questions (except demographics) were measured with a five-point scale (1: never – 5: always, 1: not at all important – 5: extremely important, 1: strongly disagree – 5: strongly agree).

The reliability test (Cronbach's alpha coefficient) for the main constructs of the survey was acceptable, since all values were above 0.70 (packaging color: 0.731, packaging material: 0.744, packaging design: 0.756, printed information: 0.727, packaging innovation: 0.752, sustainability: 0.807, purchase intentions: 0.786).

## 3. Results

As far as the demographics of the sample are concerned, 54,6% were women and 45,4% men. Many respondents (47,34%) were in the 22-23 age group, where only 15,94% were under 20 years old. Regarding the level of education, most of the respondents either have a university degree (42,03) or finished secondary education (45,89%). Around one third of the respondents work as employees in the private sector (26,09%) or in the public sector (3,86%), while 8,70% are self-employed-entrepreneurs, 6,76% are unemployed, 50,24% are students and 4,35% fall into the "other" category. Finally, 39,13% of the respondents reported a monthly household income of above 2.000 euros, 19,32% between 1.000 and 2.000 euros and 14,01% up to 1.000 euros. A considerable percentage of 27,54% preferred not to answer this question. The detailed demographics are presented at the following table (Table 1).

**Table 1:** Demographics (N=207)

| Category   | Value          | Percentage |
|------------|----------------|------------|
| Gender     | Men            | 45,4%      |
|            | Women          | 54,6%      |
| Age        | 18-19          | 15,94%     |
|            | 20-21          | 14,98%     |
|            | 22-23          | 47,34%     |
|            | 24-25          | 14,49%     |
|            | 26-27          | 7,25%      |
|            |                |            |
| Education  | Secondary      | 45,89%     |
|            | Post-secondary | 7,73%      |
|            | University     | 42,03%     |
|            | Master's       | 4,35%      |
| Occupation | Student        | 50,24%     |

|                          |                              |        |
|--------------------------|------------------------------|--------|
| Monthly Household Income | Unemployed                   | 6,76%  |
|                          | Employee in private sector   | 26,09% |
|                          | Employee in public sector    | 3,86%  |
|                          | Self-employed / entrepreneur | 8,70%  |
|                          | Other                        | 4,35%  |
|                          | Up to €500                   | 4,35%  |
|                          | €501–€1.000                  | 9,66%  |
|                          | €1.001–€1.500                | 7,73%  |
|                          | €1.501–€2.000                | 11,59% |
|                          | > €2.000€                    | 39,13% |
|                          | Did not answer               | 27,54% |

Concerning the general perceptions about packaging (Table 2), consumers perceive packaging as an important element of a product and notice it very often while shopping. However, they rarely scan the QR code on the package to access the product information and they do not seem to trust more products with a QR code on package.

**Table 2:** General perceptions about packaging

|                                                                                 | Mean | Std. Dev. |
|---------------------------------------------------------------------------------|------|-----------|
| How often do you notice the packaging of a product while shopping               | 3,64 | 1,019     |
| In your opinion, how important is packaging for a product                       | 3,97 | ,830      |
| Have you ever decided to buy a different product because of its packaging       | 3,03 | ,975      |
| For products with QR codes on their packaging, do you scan them for information | 1,67 | ,902      |
| I trust more products with QR codes on their packaging                          | 2,33 | 1,029     |

The first thing that consumers notice on packaging is expiry date, followed by product name, while very few consumers notice origin and producer/supplier information (Figure 1).

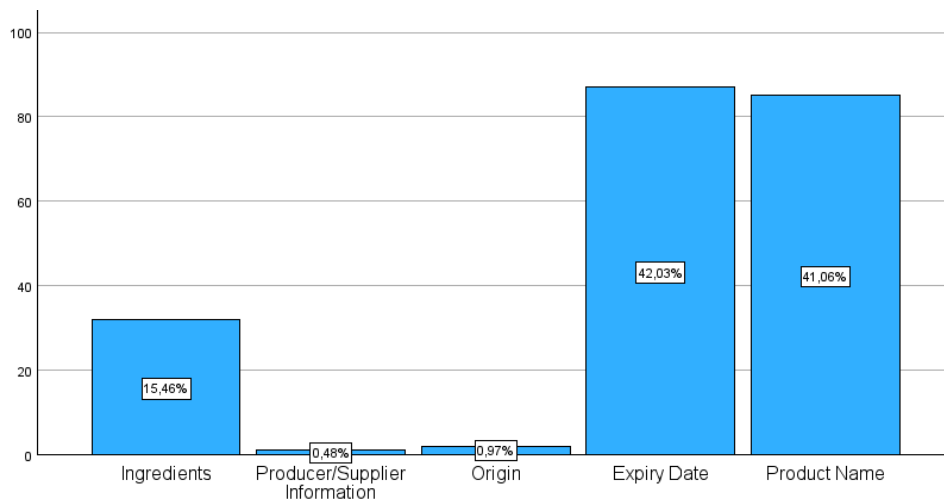


**Figure 1:** What is the first thing that consumers notice on packaging

Proceeding into more detail about consumers' perceptions regarding packaging elements, color seems to be rather significant but not highly important (Table 3).

**Table 3:** Packaging color

|                                                                       | Mean | Std. Dev. |
|-----------------------------------------------------------------------|------|-----------|
| The color of packaging influences my purchasing decision              | 3,34 | ,802      |
| Bright, vibrant colors on packaging influence my decision to purchase | 3,22 | ,804      |
| Packaging color reminds me of a specific brand                        | 3,84 | ,745      |

Perceptions about packaging material (Table 4) have relatively high mean values and consumers seem to be attracted by packaging material, although they agree that quality of packaging material does not necessarily indicates that the product is better.

**Table 4:** *Packaging material*

|                                                                   | <i>Mean</i> | <i>Std. Dev.</i> |
|-------------------------------------------------------------------|-------------|------------------|
| I prefer products with high-quality packaging materials           | 3,28        | ,886             |
| The packaging of a product attracts me to buy it                  | 3,81        | ,689             |
| The quality of packaging material indicates the product is better | 3,00        | 1,014            |
| The quality of packaging material matters to me                   | 3,66        | ,878             |

Packaging design seems to be a very important element, inspiring consumers to buy a product (Table 5).

**Table 5:** *Packaging design*

|                                                                                                | <i>Mean</i> | <i>Std. Dev.</i> |
|------------------------------------------------------------------------------------------------|-------------|------------------|
| The design of a product's packaging is important to me                                         | 4,03        | ,720             |
| The design of a product's packaging inspires me to purchase it                                 | 3,87        | ,695             |
| The design of a product's packaging creates a specific perception in my mind about the product | 3,81        | ,743             |

Packaging innovation is considered as the most important factor for Gen Z consumers, with very high mean values in every variable examined (Table 6).

**Table 6:** *Packaging innovation*

|                                                                                      | <i>Mean</i> | <i>Std. Dev.</i> |
|--------------------------------------------------------------------------------------|-------------|------------------|
| It is important for a product's packaging to have an easy opening                    | 4,31        | ,719             |
| It is important for a product's packaging to be reusable                             | 3,72        | 1,013            |
| It is important for a product's packaging to be recyclable                           | 4,08        | ,891             |
| It is important for a product's packaging to be biodegradable                        | 3,87        | ,954             |
| It is important for a product's packaging to make it easy to transport               | 4,32        | ,613             |
| It is important for a product's packaging to be durable (e.g. not break or wear out) | 4,37        | ,758             |

An interesting contradiction is highlighted in the questions regarding printed information (Table 7): although most consumers responded that it is highly important for the printed information to appear on the package, the information itself does not seem to play an accordingly important role in their purchase decision.

**Table 7:** *Printed information*

|                                                                                                         | <i>Mean</i> | <i>Std. Dev.</i> |
|---------------------------------------------------------------------------------------------------------|-------------|------------------|
| It is important for product information (e.g., expiration date, ingredients) to appear on the packaging | 4,78        | ,622             |
| I read the information on a product's packaging                                                         | 3,84        | ,781             |
| When buying a product, I evaluate it based on the information on its packaging                          | 3,46        | ,846             |

As far as the last packaging element is concerned (Table 8), purchasing products due to sustainable packaging received rather neutral responses (with a mean score of 3,00), despite the positive attitude toward sustainable packaging (mean=3,92). Respondents strongly valued the environmental contributions of sustainable packaging (mean=3,50) and its benefits over conventional packaging (mean=3,94), making such packaging both preferable (mean=3,73) and reasonable for household purchases (mean=3,29). However, regarding the safety of sustainable packaging compared to conventional packaging, responses were more neutral, with a mean score of 3,11.

**Table 8: Sustainability**

|                                                                                             | <i>Mean</i> | <i>Std. Dev.</i> |
|---------------------------------------------------------------------------------------------|-------------|------------------|
| I purchase products because of their sustainable packaging                                  | 3,00        | ,932             |
| The environmental contribution of products with sustainable packaging matters to me         | 3,50        | ,913             |
| Sustainable packaging offers more environmental benefits compared to conventional packaging | 3,94        | ,893             |
| I believe sustainable packaging is as safe as conventional packaging                        | 3,11        | 1,065            |
| In my household, it is reasonable to prefer sustainable packaging                           | 3,29        | ,820             |
| I have a positive attitude toward sustainable packaging                                     | 3,92        | ,799             |
| I prefer sustainable packaging because it is good for the environment                       | 3,73        | ,860             |

Finally, regarding the purchase intentions, Gen Z consumers seem to be highly influenced by information and innovation in product packaging, followed by packaging design and material. Sustainability seems to be an important factor; however, it is rated lower compared to the other packaging elements (Table 9).

**Table 9: Purchase intention**

|                                                                                                    | <i>Mean</i> | <i>Std. Dev.</i> |
|----------------------------------------------------------------------------------------------------|-------------|------------------|
| I would buy a product influenced by its packaging color                                            | 3,30        | ,919             |
| I would buy a product influenced by its packaging material                                         | 3,42        | ,871             |
| I would buy a product influenced by its packaging design                                           | 3,65        | ,839             |
| I would buy a product influenced by an innovation in its packaging (e.g., reusable, biodegradable) | 3,73        | ,888             |
| I would buy a product influenced by the information on its packaging                               | 3,83        | ,794             |
| I would buy a product influenced by its sustainable packaging                                      | 3,29        | ,826             |
| I would consider switching to brands that sell products with sustainable packaging                 | 3,45        | ,901             |
| In the near future, I will definitely purchase products with sustainable packaging                 | 3,57        | ,844             |

To further examine the influence of various general perceptions about packaging on consumers' purchase intention, a correlation analysis was performed. According to the results, all general perceptions are positively and moderately related to purchase intention. Similarly, the correlation analysis between purchase intention and every element of packaging showed that there is a statistically significant and positive relationship, especially between sustainability and purchase intention ( $r=0.549$ ,  $p<0.001$ ), innovation and purchase intention ( $r=0.429$ ,  $p<0.001$ ), design and purchase intention ( $r=0.401$ ,  $p<0.001$ ). The correlation between purchase intention and color and between purchase intention and material was also found to be statistically significant and positive, but weak ( $r=0.313$  and  $r=0.309$  retrospectively), while the correlation between purchase intention and printed information was found to be the weakest ( $r=0.177$ ).

#### 4. Discussion and conclusions

The present study aimed to highlight the role of packaging in supply chain management and to further explore the role of packaging characteristics on Gen Z consumers' purchase decisions and behavior, with emphasis on sustainability elements, an issue of growing attention in the relevant literature. The focus on Gen Z is a key differentiating aspect of our research, due to the unique consumer behavior characteristics of this generation and the high values of issues related to sustainability.

According to the results, packaging elements such as design, innovation and sustainability have a significant impact on Gen Z consumers' purchase behavior, while in other studies conducted in samples with all consumer generations (Nanos et al., 2025) these elements were not so important. Similarly, there is a more evident intention of Gen Z consumers to purchase products influenced by

sustainable packaging characteristics and to consider switching to a brand that offers such products, compared to consumers from older generations.

Despite its valuable contributions, the study has some limitations. First, the sample size was limited, thus restricting the generalizability of the findings to broader consumer populations. Also, since the questionnaire was distributed through social media, there may be a sampling bias because social media tend to connect people with similar demographics, backgrounds and geographic locations. Finally, while the study assessed certain elements of packaging, other factors such as branding and pricing of products were not explicitly considered, which could also influence consumer decisions.

Future research efforts could reach Gen Z consumers across different geographical regions and/or countries, to discover similarities or differences on perceptions especially concerning sustainability, since awareness on this issue and green consumer behavior varies across consumers in different countries (Nanos et al., 2025).

The implications of this research can inform marketing and logistics decisions related to packaging design, cost-efficiency and sustainable material selection. By linking Gen Z consumer behavior with operational decision-making, this study contributes to the broader understanding of how demand-side preferences shape upstream activities in production and distribution systems, as well as in marketing strategy formulation.

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## **Sustainability strategies and shareholder outcomes in bank mergers and acquisitions**

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### **Abstract**

This paper aims to investigate the performance of bank M&As from the targets' perspective, considering the role of acquirers' ESG performance. Prior literature suggests that acquirers' ESG scores constitute a factor affecting their performance; however, limited attention has been paid to the impact of acquirers' ESG performance on the targets' shareholder value. Thus, we evaluate whether announcement returns to targets are influenced by the level of acquirers' sustainability performance. Using a sample of M&As in the U.S. banking sector over the period 2012–2023, we assess the valuation effects of bank M&As for target shareholders, applying the event-study methodology. Cumulative Abnormal Returns (CARs) over various event windows surrounding the M&A announcements are estimated using the market-adjusted model, with statistical significance tested using the BMP-test and the Corrado-test. To assess the impact of acquirers' ESG scores on targets' CARs, we apply univariate and multivariate analyses. The results show that, on average, target firms' shareholders gain 15.8% over the three-day (-1, 1) event window upon M&A announcements. The positive valuation effects are statistically significant at the 1% level using both the BMP-test and the Corrado-test. Applying alternative event windows, the results confirm positive valuation effects of 16.4% in the five-day (-2, 2) event window. Using two sub-samples based on the acquirers' ESG score, the univariate analysis with the t-test indicates that targets' returns are 5.7% lower for M&As announced by acquirers with high ESG performance (above median) compared to those announced by acquirers with low ESG performance. The same results are confirmed using the non-parametric Mann-Whitney U test. After controlling for deal-specific and target-specific characteristics, the multivariate regression analysis with robust standard errors and year-fixed effects confirms that acquirers' ESG performance has a negative and statistically significant (at the 5% level) effect on targets' gains. The results remain qualitatively similar using alternative event windows surrounding the deal announcements. Overall, we show that the acquirers' ESG performance is a crucial factor reflecting their strategy towards ESG investments, thereby affecting the targets' shareholder value upon M&As. Although targets' shareholders gain value upon M&As, the acquirers' ESG performance is negatively associated with their acquisition gains.

**Keywords:** *Bank Mergers and Acquisitions; Event-Study Methodology; ESG Performance, Sustainable Investments; Acquirer-Target Dynamics*

# **Executive compensation and firm performance: evidence from the FTSE 100**

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## **Abstract**

In the dynamic landscape of corporate governance and performance evaluation, the relationship between executive compensation and firm performance has been a subject of persistent scrutiny and debate. Popescu (2019) states that understanding how executive compensation structures relate to elite firms' performance is not only academically intriguing but also holds significant practical implications for investors, policymakers, and corporate leaders alike. While executives are crucial in steering an organization's strategic direction and driving its success, excessively high compensation packages can raise concerns about fairness, shareholder value, and potential agency problems (Gupta and Wowak, 2017). However, the debate surrounding executive compensation has been further fueled by recent developments and crises. Investors are increasingly vocal about opposing exorbitant executive compensation packages, particularly when they are not demonstrably linked to company performance (Gande and Kalpathy, 2017). This pressure can lead to greater scrutiny of compensation structures and calls for increased transparency. The excessive bonuses awarded to executives of financial institutions, even in the wake of massive taxpayer bailouts, fueled public outrage and intensified calls for greater transparency and accountability in executive compensation. Furthermore, there have been growing societal concerns about income inequality that have placed executive compensation under a microscope, raising questions about the fairness of excessive pay packages compared to average worker wages (Vo and Canil, 2019).

The existing literature presents mixed evidence regarding the relationship between executive compensation and firm performance, indicating a need for further investigation. According to Akanfe and Oladipo (2017), most empirical research findings suggest that executive compensation significantly impacts firm performance. However, many studies conducted in developed economies have overlooked market indicators such as stock price, market capitalization, and Tobin's Q, favoring accounting measures of firm performance instead. While accounting metrics offer valuable insights into a company's financial health, they may not fully capture market perceptions and investor sentiment, which can significantly influence firm value and performance. This knowledge gap highlights the necessity of incorporating market-based measures alongside traditional accounting metrics to achieve a more comprehensive understanding of the relationship between executive compensation and firm performance.

Using static panel data regression analysis, this study examines the relationship between executive compensation and firm performance among FTSE 100 companies over a period from 2019 to 2023. Specifically, this research analyzes various components of executive compensation, including annual salary, bonuses, stock options, pension benefits, retirement perks, and family-related compensation/benefits, to examine their impact on market value and net profits. The results of the regression analysis indicate that higher annual salaries and bonuses for executives are associated with improved firm performance. Conversely, stock options do not have a significant effect on financial

performance. Additionally, pension benefits and family-related compensation are negatively correlated with lower profits. This study suggests that executive pay structures should be carefully designed to enhance profits without compromising the company's overall performance.

**Keywords:** *Financial performance, bonuses, stock options, pension benefits, FTSE 100.*

## **Determinants of peer-to-peer lending expansion: the role of Economic Freedom Index**

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### **Abstract**

The global rise of peer-to-peer (P2P) lending is posing a challenge to the worldwide banking system. This research explores the key factors affecting the development of P2P lending, with a specific focus on examining the influence of economic freedom levels in U.S. states from 2007 to 2020. The study is motivated by the hypothesis that economic freedom can positively influence P2P lending volume, given its connection to institutional variables that can shape the dynamics of the credit market. For this analysis, we employ hand-collected data from LendingClub platform and Economic Freedom Index of North America. Various other financial, economic and demographic variables from all 50 U.S. states are incorporated to investigate their impact on P2P lending market. Panel data techniques are employed for the empirical analysis. Our results, in line with prior research, show that P2P lending activities penetrate areas with higher market concentration and financial development, as well as fewer bank branches. Moreover, economic variables and demographic determinants play a crucial role in the expansion of crowdlending. The innovation of this study is the introduction of the Economic Freedom Index and its sub-indices in order to explain the development of P2P lending. The analysis revealed significant positive correlation between P2P lending expansion and economic freedom at the state level. In particular, high levels of the sub-indices relative to credit market regulation, business regulation, and sound money are positively related with crowdlending growth. However, the freedom to trade internationally do not appear to have a significant influence on this market.

**Keywords:** *economic freedom, FinTech, peer-to-peer lending, marketplace lending, United States*

# **Assessing the impact of supply chain risks on supply chain management performance in engineering firms – a case study of power plant sector in Mauritius**

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## **Abstract**

In recent years, the widespread disruptions caused by natural disasters or man-made acts have shown that supply chains are vulnerable to various risks and that effective risk mitigation strategies are needed. The aim of this study is to investigate the risks in the supply chain of a power plant in Mauritius and their impact on performance. 22 in-depth interviews were conducted with employees from different departments of the power plant. The data was analyzed using NVivo and a thematic analysis. The results show that the power plant has several operational, environmental and logistical risks that have a significant impact on on-time delivery, cost efficiency and customer satisfaction. Risk mitigation strategies and advanced technologies are required for effective risk management, but financial and organizational challenges should be overcome during implementation.

**Keywords:** *supply chain risks, supply chain performance, risk mitigation.*

## **1. Introduction**

In recent decades, supply chain disruptions have become more frequent due to economic crises, natural disasters, terrorism and various other causes. These disruptions can significantly affect the short-term performance of organizations and potentially have a long-term negative impact on financial results (Tang, 2006).

In businesses, supply chain disruptions become more extensive, with the magnitude and frequency of risk events increasing. Uncertainty in the business landscape creates supply chain risks that can be considered as potential performance disruptors (Gurtu and Johny, 2021). Numerous incidents have shown how disruptions at any point in the supply network can directly affect a company's ability to operate, deliver products or provide essential services. For example, the tsunami in Japan in 2011 had a lasting global impact on the automotive industry, while severe flooding in Thailand disrupted supply chains for both electronics and vehicle manufacturing (Katsaliaki et al., 2021). In addition to natural

disasters, man-made disruptions, such as changes in global trade policies, tariffs, Brexit (Banker, 2019) and geopolitical conflicts like the war between Russia and Ukraine, have further complicated global supply chains, affecting various industries from semiconductors and automobiles to food (Simchi-Levi and Haren, 2022). The COVID-19 pandemic has underscored the vulnerability of global supply chains as lockdowns in central China (Araz et al., 2020) triggered widespread operational challenges. These included halted production, orders cancelation, and supplier liquidity crises (Hohenstein, 2022; Cagri Gurbuz et al., 2023), reinforcing the need for effective supply chain risk management (SCRM) to ensure continuity, competitiveness and survival.

SCRM is a systematic approach to identifying, assessing, mitigating and monitoring potential supply chain disruptions to reduce their negative operational impact (Aqlan and Lam, 2016). Vicente (2024) outlines best practices such as supplier diversification, proximity-based sourcing, risk tolerance assessment and worst-case scenario simulation for robust risk management. As global supply chains become increasingly complex, companies face diverse risks that can threaten their product and service delivery capabilities, potentially disrupting operations and causing significant financial losses (Emrouznejad et al., 2023). The need for SCRM is well established, as supply chain risks have been shown to negatively affect supply chain performance (Wagner and Bode, 2008; Shahbaz et al., 2019).

Despite its growing importance, SCRM is a relatively new and evolving field. Most existing research focuses on developed countries, with limited studies from developing regions (Prakash et al., 2017), and non-manufacturing sectors have not yet been sufficiently researched (Ajwang and Onyango, 2022). The literature has primarily used modeling and survey methods to analyze risk impacts, while case studies, which are of great value for investigating phenomena in real-world contexts, are comparatively rare. Case studies or interviews can help explain why risks manifest differently within similar settings (Pham et al., 2023), allowing for tailored solutions and sector-specific, adaptable risk management strategies (Ganeshan et al., 2020).

Building on this gap, the proposed research examines the impact of supply chain risks on supply chain management (SCM) performance in engineering firms, with a case study focusing on a power plant in Mauritius. The aim of the study is to identify the key supply chain risks, assess their impact on performance metrics and explore existing and potential mitigation strategies in a developing island economy. The research seeks to answer the following questions:

RQ1: What are the prevalent SC risks specific to the power plant?

RQ2: How do the identified SC risks affect key SCM performance indicators, such as on-time delivery, quality, cost efficiency, flexibility, and customer satisfaction within the firm?

RQ3: What practices are currently implemented by the power plant to mitigate SC risks and what other strategies can aid in effectively managing SC risks and enhancing SCM performance for the firm?

## **2. Literature review**

### **2.1 Supply Chain Risk Management**

Scholars in supply chain risk management (SCRM) have diverse perspectives on its principles, applications and scope, reflecting the complicated and multidimensional nature of risk management in complex supply chains. Broadly, SCRM aims to minimize disruptions by adopting a structured approach to identifying potential risks across various nodes or links within an organization's supply chain network. These strategies are designed to reduce the negative impacts associated with supply chain vulnerabilities (Ganiyu et al., 2020).

Jüttner et al. (2003) define supply chain risks as the likelihood and consequences of imbalances between supply and demand. They conceptualize SCRM as the coordinated identification and management of such risks among supply chain partners with the aim of mitigating overall vulnerability. This perspective emphasizes the role of uncertainties in influencing information, material and product flows across organizational boundaries.

Building on this, Wu et al. (2006) introduced an integrated approach to classifying, managing and evaluating inbound supply chain risks using the analytical hierarchy process. Similarly, Foerst et al. (2010) focused on supplier management within the SCRM framework, detailing a systematic process that includes identifying risks, assessing their severity, quantifying potential consequences, making informed decisions and measuring performance, particularly in relation to supplier sustainability.

In a comprehensive literature review, Ponis and Ntalla (2016) identified significant gaps in SCRM research. They emphasized the need for a more holistic approach and highlighted the often-overlooked behavioral dimensions, such as the risk behavior of decision makers. Fan and Stevenson (2018) echoed these concerns, arguing for a broader theoretical engagement to enhance the understanding of SCRM. They advocate for a comprehensive view of the entire SCRM process, defining it as “The identification, assessment, treatment, and monitoring of supply chain risks, with the aid of the internal implementation of tools, techniques and strategies and of external coordination and collaboration with supply chain members so as to reduce vulnerability and ensure continuity coupled with profitability, leading to competitive advantage”.

## **2.2 Supply Chain Disruptions**

Supply chain disruptions refer to unforeseen events that interrupt the normal flow of goods and materials in the supply chain. These disruptions can arise from natural disasters such as floods and earthquakes, as well as from human-related causes, both intentional or accidental, such as industrial accidents or terrorist attacks (Snyder et al., 2015). Even minor disruptions can escalate significantly, triggering ripple effects across the supply chain network (SCN). A disruption at a local level can propagate both upstream and downstream through the material flow and eventually affect the entire SCN in unpredictable ways, making it difficult to predict and manage such events (Li et al., 2021). These disruptions are often due to a number of unforeseen factors, including supply shortages, operational failures, distribution bottlenecks and demand fluctuations (Novoszel and Wakolbinger, 2022). For example, suppliers may experience lower production capacity due to raw material shortages, financial limitations, labour scarcities or inefficiencies caused by natural or man-made disasters. Similarly, distribution can be hindered by problems such as border restrictions, inadequate transportation infrastructure or lack of labour. On the demand side, changing customer needs, triggered by psychological reactions or evolving market conditions, can further exacerbate disruptions across the value chain.

The COVID-19 pandemic represents a distinctive case study in supply chain disruption due to its global scale and long-lasting impact. Unlike past events such as the earthquake in Japan or previous disease outbreaks, which were geographically contained and short-lived, COVID-19 exploited the vulnerabilities of globally interconnected supply chains. It disrupted both supply and demand dimensions across security, stability, availability and visibility (Choudhury et al., 2022).

Disruptions not only temporarily halt supply chain operations, but without adequate preparation and precautions, they can also significantly extend the recovery time for the affected systems. The severe consequences of supply chain disruptions underscore the critical importance of supply chain risk management practices (Tang and Musa, 2011).

## **2.3 Supply Chain Risks**

The concept of risk has been defined in numerous ways, but most definitions have three core dimensions in common: the likelihood of a particular event occurring, the consequences of that event,

and the causal pathway leading to it (Ritchie and Brindley, 2007). Researchers have proposed a wide range of frameworks for identifying and categorizing risks within organizations. In the context of supply chains (SC), risks are broadly categorized into operational risks and disruption risks (Tang, 2006). Operational risks refer to inherent uncertainties related to customer demand, supply and costs, while disruption risks stem from major events such as natural disasters, man-made disasters or economic crises. While disruption risks typically have a more severe impact on the business than operational risks, some SC risks can be prevented and others mitigated to enable a quick recovery after a disruption (Fahimnia et al., 2015).

Juttner et al. (2003) propose a classification into three categories: Environmental risks arising from interactions between the supply chain and the environment, organizational risks occurring within the boundaries of parties in the supply chain, and network-related risks stemming from interactions between organizations within the supply chain.

Several researchers have further refined risk categorization methods. Chopra and Sodhi (2004) identified supply-related, customer-related and internal risks inherent in all supply chains. Supply risks include issues around cost, quality and commitment, process risks involve quality control, time delays and capacity constraints in logistics and internal operations, and demand risks relate to fluctuations in customer demand (Tang and Tomlin, 2008). Oke and Gopalakrishnan (2009) stated that risks can be categorized based on their likelihood and impact, identifying not only high probability and low impact (frequent and inherent) risks and low probability and high impact (disruptive) risks, but also medium probability and moderate impact risks, which vary depending on the structure or context of the supply chain.

Manuj and Mentzer (2008) expanded existing taxonomies to include supply, operational, demand and security risks along with macroeconomic risks (wage rates, interest rates, exchange rates), political risks (government measures), competitive risks (competitors' activities) and resource risks (unforeseen resource requirements). Rao and Goldsby (2009) proposed a typology that includes environmental, industry, organizational, problem-specific and decision-maker-related risks. Vikulov and Butrin (2014) focused on risk identification at specific nodes of the SC network and categorized risks across the stages of suppliers, transportation, warehousing and production. Shahbaz et al. (2019) emphasized the importance of risk management in improving SC performance by dividing risks into logistics-related, collaboration-related, and financial types and highlighting how different risks uniquely affect various components of the supply chain.

## **2.4 Supply Chain Performance**

Supply chain performance refers to the capability of a supply chain to deliver the right product to the right place at the right time, all while minimizing logistics costs. This definition includes key elements such as delivery timing, cost efficiency and value creation for the end consumer (Leonczuk, 2016). As a critical component in assessing supply chain activities, supply chain performance influences strategic, tactical and operational decision-making. It encompasses various dimensions, including monetary metrics such as costs and profits, which reflect the economic efficiency of operations. In addition, key performance indicators, such as adherence to delivery times and quality standards, are crucial for gauging customer satisfaction (Novoszel and Wakolbinger, 2022).

However, identifying a suitable set of key performance indicators (KPIs) to measure supply chain performance remains a complex task. There is a recognized need for an integrated performance measurement framework that combines multiple dimensions, financial and non-financial, qualitative and quantitative, into a coherent system that reflects the overall performance of the supply chain. In retail, for example, KPIs are typically grouped into four main categories: Transportation Optimization, Information Technology Optimization, Inventory Optimization and Resource Optimization (Anand and Grover, 2015).

Shahbaz et al. (2019), in their study on the impact of risk on supply chain performance, emphasized the need to use both financial and non-financial indicators, pointing out that using financial metrics alone is not sufficient for capturing overall performance. Similarly, Pham et al. (2023), in their literature review, examined how different types of risks affect supply chain performance. Their findings highlighted the complex and multifaceted nature of this relationship, which is influenced by a number of factors including antecedents, mediators, moderators and risk mitigation strategies.

Based on the literature review, the key SC risks and SCM performance indicators identified for this study are presented in Tables 1 and 2, respectively.

**Table 1: Key Supply Chain risks**

| Supply Chain Risks | Description                                                                                                                  | References                                               |
|--------------------|------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| Operational        | They include uncertainties like uncertain customer demand, supply fluctuations, and cost variability.                        | Tang (2006)<br>Novoszel and Wakolbinger (2022)           |
| Disruption         | They result from major disruptions triggered by natural calamities, man-made disasters, or economic crisis.                  | Tang (2006)<br>Novoszel and Wakolbinger (2022)           |
| Environmental      | They stem from supply chain-environment interactions, including human errors, socio-political events, and natural disasters. | Juttner et al. (2003)                                    |
| Network            | They result from interactions between supply chain organizations, causing damage from improper interactions.                 | Juttner et al. (2003)                                    |
| Demand-related     | They arise from demand variations, supplier capacity changes, and lead time unpredictability.                                | Oke and Gopalakrishnan (2009)<br>Chopra and Sodhi (2004) |
| Logistic side      | Issues related to transportation, materials handling, supply planning and third-party logistics service providers.           | Shahbaz et al. (2019)                                    |
| Collaboration side | Challenges evolving from the complexity of partnerships, and differences in interests within the supply chain.               | Shahbaz et al. (2019)                                    |
| Finance side       | Financial challenges that can impact the ability of supply chain members to produce and supply goods/services.               | Shahbaz et al. (2019)                                    |

**Table 2:** *SCM Performance Indicators*

| SC Performance Indicators | Description                                                                                    | References                                               |
|---------------------------|------------------------------------------------------------------------------------------------|----------------------------------------------------------|
| Operational               | Including on-time delivery, quality, cost, efficiency, flexibility, and customer satisfaction. | Shahbaz et al. (2019)                                    |
| Financial                 | Measuring financial outcomes and the impact of risks on financial metrics.                     | Shahbaz et al. (2019)<br>Novoszel and Wakolbinger (2022) |
| Logistic                  | Measuring the efficiency of logistics and transportation within the supply chain.              | Anand and Grover (2015)                                  |
| Collaboration             | Assessing the effectiveness of collaborations within the supply chain.                         | Ganiyu et al. (2020)                                     |
| Resource optimization     | Focusing on the efficient use of resources within the supply chain.                            | Anand and Grover (2015)                                  |

### 3. Research design, data collection and analysis

This study examines the power plant sector in Mauritius, characterized by heavy reliance on foreign sourcing, resulting in long lead times for materials and expertise. Through qualitative investigation, it aims to uncover the unique supply chain risks and performance challenges within this specific industry context. The research employs a case study approach to examine processes and interactions in depth and provide a comprehensive insight into the Mauritian power plant sector (Njie & Asimiran, 2014). A qualitative methodology was chosen to allow participants to authentically express their priorities and perspectives and reveal their interpretations of industry events and challenges (Meyer et al., 2019). Through purposive sampling, 22 participants with diverse roles in procurement, logistics, operations and maintenance were selected based on their relevant expertise rather than demographic factors. Most participants had 5 to 20 years of industry experience, providing varied perspectives on supply chain risks and performance challenges in the power plant sector. Semi-structured interviews served as the primary data collection method, selected for their ability to elicit insights beyond surface-level responses. Interviews were conducted both in person at the plant facilities and via telephone to accommodate participants' schedules and preferences. Interviews lasted an average of 105 minutes, and participants were assured confidentiality and encouraged to share their perspectives without concern for "correct" answers. The structure of the interviews was based on previous research, using Tables 1 and 2 as the basis for designing the questionnaire to explore specific areas of risk. The questionnaire (Appendix A) consists of four sections: Section A captures respondent profiles. Section B focuses on supply chain risk identification, including descriptions, triggers and impacts. Section C examines risk impacts on various supply chain performance indicators, disruptions and resilience strategies. Section D explores risk mitigation suggestions, including practices, technology integration and implementation challenges. Data underwent multiple review cycles and was subsequently coded and analyzed using NVivo software. The analysis yielded 8 distinct themes, which are discussed in the following section.

## 4. Results

### 4.1 Supply chain risks

Prevalent SC risks in Mauritius: Participants highlighted reliance on international suppliers, delays, quality concerns, global economic shifts, and logistics as major SC risks in Mauritius' engineering sector. As noted by P7, Head of Mechanical Department: *“In the engineering sector of Mauritius, risks include long wait times for critical equipment, variations in quality from suppliers, logistical hurdles impacting on-time deliveries, depreciation of Mauritian rupees and reliance on international suppliers for specialized equipment”*

Risks in the power plant: Key risks include delays, price fluctuations, regulatory/quality concerns, logistics issues, and reliance on international suppliers. Long lead times for specialized equipment, shipment delays from freight issues, and payment delays strain supplier relationships, impacting spare part availability, causing downtime, and potential penalties from the Central Electrical Board (customer) due to service interruptions. As highlighted by P6, Maintenance Manager: *“We’ve faced challenges related to delayed shipments of spare parts, occasional quality issues in machinery received, and logistical constraints with our freight agents affecting timely equipment maintenance. Most of our equipment and parts need to be ordered internationally. If we choose local suppliers to order the part for us, their markup is very high leading to high-cost spares. Lead time is also a major issue. It happened in the past when suppliers did not respect the lead time. Also, many international suppliers close during summer holidays in Europe and around Christmas and new year globally. Price fluctuations are another big risk – decrease in selling price of electricity and drastic increase in price of coal.”* These findings align with risk classifications proposed by Cavinato (2004) and Harland et al. (2003).

Emerging risks: 16 and 14 out of 22 participants highlighted emerging risks such as standards and regulations, along with geopolitical tensions respectively, as potential future concerns. Sustainability considerations are driving shifts in raw material sourcing and environmental regulations, prompting a potential transition from coal to renewable fuel sources for electricity production. Factors like trade restrictions, geopolitical tensions, and transportation challenges may result in delays, increased costs, or material shortages, impacting project timelines and budgets. These findings corroborate with the findings of (Cucchiella and Gastaldi, 2006).

Risk sources and triggers: Participants discuss process issues (14) and global economic disruptions (12) as primary SC risks sources/triggers. Process problems involve inventory, handling inefficiencies, and human errors in orders. Global disruptions include currency fluctuations, market volatility impacting raw material prices. As mentioned by P14, Procurement Executive: *“...Triggers might include factory shutdowns, delays in customs clearance... supplier bankruptcy, production issues, or changes in their business priorities impacting the supply chain...”*. These findings align with disruption and operational risks identified by Tang (2006).

### 4.2 Supply chain performance

Challenges in meeting performance goals: SC risks like delays, price fluctuations, quality and logistical issues have a profound impact on the timely delivery of crucial spare parts, causing operational downtime for the power plant. This results in penalties from CEB (customer) due to disruptions in electricity production. Late payments to suppliers not only lower the worth of supplies but also lead to compromises in quality due to financial strain on suppliers. Using lower-quality parts causes breakdowns in the plant. As noted by P20, Procurement & logistics Supervisor: *“For instance, drastic increase in coal price and decrease in selling price of electricity to the CEB have led to operational disruptions. Issues with freight agents affected our on-time delivery and alternate sourcing compromised quality.”* To mitigate delays, the plant resorts to alternative, albeit more expensive, sources for spare parts, impacting overall cost efficiency. When disruptions occur, the

plant struggles to swiftly adapt, leading to extended periods of downtime before alternative solutions are secured. Ultimately, these challenges directly affect customers' satisfaction with electricity production and result in penalties due to inconsistent service. As P12, Planner Procurement mentioned: *"SC risks occurred when a key supplier faced labor strikes, leading to production delays and difficulties meeting delivery schedules."* These findings align with the work from Duong et al., (2023) who concluded that delays and supply risks have a significant effect on supply chain performance.

### 4.3 Risk mitigation strategies

Current strategies and their impact on performance: Participants emphasized that diverse sourcing options, backup suppliers, buffer stock, regular assessments and collaboration with suppliers are common practices to mitigate risk in SC. These increase resilience, reduce delays and ensure smoother operations, which improves SCM performance. P22, Maintenance Planner noted: *"Diversified sourcing, maintaining buffer stocks, and continuous risk assessments aid in mitigating potential disruptions during the critical maintenance period"*. These proactive measures result in improved on-time delivery, fewer disruptions and greater supply chain reliability, as explained by P10, Procurement Officer: *"Our company adopts a proactive supplier performance evaluation system and inventory management, generating effectiveness in risk mitigation and improving SCM efficiency by reducing lead times"*. These findings are in line with Kibuli (2016) and Dohale et al. (2021) who discuss multiple sourcing, redundancy and collaboration with suppliers as effective risk management strategies.

Technology adoption: All 22 participants confirmed the company's plan to invest in technology as a novel insight into SC risk mitigation. Strengthening resilience, scenario planning and proactively adapting to regulatory changes were also highlighted. P11, Logistics Coordinator noted: *"The future plan for integration of technology will facilitate automated monitoring and alerts, improving risk assessment accuracy and enabling swift responses to potential disruptions in our supply chain."* In particular, almost all participants mentioned the use of Maximo, a computerized asset management software, for inventory monitoring, inventory management and trend analysis. As P7, Head of Mechanical Department mentioned: *"Analysis in Maximo enables us to monitor equipment performance and inventory level."* Research shows that technology is revolutionizing supply chain risk management practices, increasing supply chain visibility and enabling companies to monitor the movement of goods and assets in real time (Olutimehin et al., 2024).

Challenges with SC risk mitigation: There are some challenges in implementing new strategies to mitigate SC risks. Participants cited budget constraints, cost-benefit ratio, limited resources and resistance to change as the biggest obstacles. As P22, Planner highlighted: *"Complexities in technological adoption and budget constraints pose challenges in implementing risk mitigation strategies."* These findings are in line with the work from Reshad et al., (2023) who identified financial barriers and information-related barriers as major challenges in implementing SCRM.

## 5. Discussion, conclusions and considerations for practice

This study examined the critical SC risks that affect a Mauritius-based power plant and how they impact the engineering sector's operations. The study identified key challenges including dependency on international suppliers, delays, quality issues, and logistical obstacles, all directly impacting crucial SCM performance indicators like on-time delivery, customer satisfaction, cost efficiency, and quality. This research confirms previous academic findings on SC risks (Chopra & Sodhi, 2004; Tang & Tomlin, 2008; Manuj & Mentzer, 2008; Vikulov & Butrin, 2014) who classify risks based on supply, process, demand, security, macro, policy, and competitive factors. Interestingly, the participants in this study did not indicate any collaboration-side and network-related risks, possibly

due to well-established relationships in their supply chain. The emergence of new risks like geographic positioning, geopolitical tension, technology, and transportation/logistics issues highlight the evolving challenges within SC. The strategies proposed by the participants, including diversified sourcing and supplier evaluations, correlate with academic recommendations for mitigating supply chain risks (Foerst et al., 2010; Trkman et al., 2012). This case study offers insights due to its unique operational context of a power plant, where almost all expertise and spare parts are fundamentally sourced from abroad. The findings extend existing literature that primarily focused on theoretical frameworks and broader risk categorization without specific contextual examples such as a power plant setting as observed in Mauritius. From a practical perspective, organizations should identify current and emerging risks in their supply chain and assess their potential impact. Technology serves as a key enabler in monitoring risks. However, SCRM strategies implementation requires allocating investments, comprehensive cost-benefit analyses and strategic change management.

## 6. Limitations and considerations for future research

This study has some limitations. The scope, focusing on a power plant in Mauritius, may limit the applicability of the results to the broader engineering sector or other industries. The participants' perspective was crucial to the results, which carries the risk of subjectivity. The study could increase reliability by triangulating data sources, including different stakeholders or adding quantitative measures to complement qualitative findings. A broader sample across multiple plants or sectors could provide a more comprehensive overview of SC risks and mitigation strategies. Future research could compare SC risks in different power plants and contexts and consider the influence of external factors. Investigating how market and regulatory differences influence risk management can provide valuable insights. Analyzing the long-term impact of identified risks on SC performance indicators helps prioritize mitigation strategies. Developing a quantitative framework for assessing power plant-specific SC risks that integrates objective metrics to proactively identify and prioritize risks has potential.

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# **Balancing the books and the planet: ethical accounting in ESG-driven strategic decision-making**

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## **Abstract**

As Environmental, Social, and Governance (ESG) considerations become central to corporate strategy, ethical challenges in accounting and financial reporting are increasingly scrutinized. This paper explores the ethical dilemmas faced by accountants and decision-makers when integrating ESG principles into financial disclosures and strategic planning. It examines the fine line between ethical ESG reporting and greenwashing, the role of accountants in ensuring transparency and accountability, and the impact of regulatory frameworks on ethical decision-making. Additionally, the paper discusses the implications of emerging technologies, such as AI and blockchain, in maintaining ethical ESG reporting standards. The discussion highlights best practices for ethical financial reporting and the strategic role of accountants in fostering responsible corporate behavior.

**Keywords:** *Ethical Accounting, ESG Reporting, Greenwashing, Corporate Transparency, Financial Ethics, Sustainability Accounting, Strategic Decision-Making, Regulatory Compliance, AI in Accounting, Blockchain Transparency*

## **1. Introduction**

In recent years, Environmental, Social, and Governance (ESG) considerations have shifted from peripheral concerns to central pillars of corporate strategy, fundamentally reshaping how firms approach value creation and long-term resilience. As global challenges such as climate change, social inequality, and governance failures intensify, stakeholders - including investors, regulators, consumers, and employees - have heightened their expectations for corporate accountability beyond traditional financial metrics. ESG is no longer merely a reputational tool or an extension of corporate social responsibility; it is now increasingly embedded in risk management, capital investment decisions, and strategic planning processes. Eccles et al., (2014) provide empirical evidence that companies with high sustainability performance outperform their peers in both accounting and stock market returns, attributing this advantage to superior stakeholder engagement and internal governance practices. Likewise, the financialization of ESG through ratings, indices, and integrated reporting frameworks has made sustainability performance a tangible and actionable dimension of corporate competitiveness (Friede, Busch, & Bassen, 2015).

At the same time, institutional pressures are accelerating ESG integration into corporate governance structures. Regulations such as the European Union's Corporate Sustainability Reporting Directive

(CSRD) and the establishment of the International Sustainability Standards Board (ISSB) are creating a more standardized and enforceable framework for sustainability disclosures. These developments underscore the shift from voluntary ESG communication toward mandatory, auditable reporting practices. Scholars such as Gray, Adams, and Owen (2014) argue that this evolution reflects not only compliance with external mandates but also a deeper transformation in the understanding of corporate purpose—one that aligns ethical accountability with strategic intent. ESG is increasingly viewed as both a moral obligation and a strategic imperative, placing accountants and financial professionals at the intersection of fiduciary responsibility and broader societal accountability. Their role in ensuring the integrity, credibility, and ethical grounding of ESG disclosures has never been more critical.

As Environmental, Social, and Governance (ESG) considerations become embedded in corporate governance and strategy, the intersection of ESG, ethics, and accounting has emerged as a critical frontier for both academic inquiry and professional practice. Accountants play a pivotal role in translating ESG principles into measurable disclosures, yet this process often involves navigating complex ethical terrain. Traditional financial reporting frameworks were not designed to accommodate the nuanced and sometimes ambiguous nature of ESG data, making it difficult for accountants to adhere to both ethical integrity and managerial expectations (Michelon, Pilonato, & Ricceri, 2015). Moreover, ESG reporting is not merely a technical task but a socially embedded practice shaped by institutional pressures, stakeholder scrutiny, and evolving norms of corporate responsibility (Gray et al., 2014). Ethical decision-making in this space is often influenced by conflicting demands: the push for transparent and accountable reporting on one hand, and the desire to maintain a favorable corporate image on the other (Cho et al., 2015). This tension underscores the importance of ethical awareness and professional judgment in shaping credible ESG disclosures.

Despite the growing literature on sustainability accounting, a significant research gap persists regarding the ethical challenges posed by regulatory mandates, stakeholder activism, and emerging technologies such as AI and blockchain. While regulatory frameworks like the EU Corporate Sustainability Reporting Directive (CSRD) and the International Sustainability Standards Board (ISSB) aim to enhance the comparability and reliability of ESG information, they also introduce rigidities that may compromise ethical judgment, especially when firms prioritize compliance over substance (Mio et al., 2022). This raises critical research questions: How do accountants ethically navigate the strategic imperatives of ESG disclosures? What is the role of emerging technologies in either supporting or undermining ethical reporting practices? And how can organizations credibly differentiate between genuine sustainability efforts and greenwashing? These inquiries demand a multidisciplinary exploration of how regulatory, technological, and organizational factors interact to shape ethical behavior in ESG reporting. As such, this paper contributes to advancing the discourse on ethical sustainability accounting by positioning accountants not merely as technical reporters but as moral agents within increasingly complex organizational ecosystems.

## **2. Theoretical Framework**

### **2.1. Ethical theories applied to accounting (e.g., deontology, utilitarianism, virtue ethics)**

Ethical decision-making in accounting, particularly within the context of ESG disclosures, is often evaluated through the lens of normative ethical theories such as deontology, utilitarianism, and virtue ethics. Deontology emphasizes duties and principles, making it especially relevant to professional codes of conduct followed by accountants, such as objectivity and integrity, irrespective of consequences (Duska, Duska, & Ragatz, 2011). In contrast, utilitarianism evaluates actions based on their outcomes, suggesting that ESG reporting should maximize benefits for the widest group of stakeholders, including society and the environment (Watts & Zimmerman, 1986). Meanwhile, virtue ethics focuses on the character of the decision-maker, arguing that the accountant's internal moral compass—shaped by values like honesty and courage—plays a key role in navigating complex ESG

dilemmas (Mintz, 1995). These ethical frameworks are foundational in guiding how professionals approach transparency and truthfulness in reporting practices, especially when confronted with pressures to obscure ESG shortcomings.

## **2.2. Legitimacy theory, stakeholder theory, and institutional theory**

Three prominent organizational theories—legitimacy theory, stakeholder theory, and institutional theory—offer important lenses for understanding corporate behavior in ESG reporting. Legitimacy theory posits that firms disclose ESG information to maintain alignment with societal expectations and preserve their social license to operate (Deegan, 2002). Stakeholder theory expands this view by emphasizing the need to account for the interests of a broad range of actors—not only shareholders, but also employees, customers, communities, and environmental entities (Freeman, 1984). Meanwhile, institutional theory explores how normative pressures from regulators, professional bodies, and peers shape ESG disclosure practices through processes of isomorphism (DiMaggio & Powell, 1983). Together, these theories highlight the systemic pressures on organizations and accountants to not only act ethically but to appear ethical in their reporting, underlining the importance of transparency in response to evolving social norms and institutional expectations.

## **2.3. Conceptual definition of greenwashing vs. ethical ESG reporting**

Greenwashing represents a critical ethical pitfall in ESG reporting, characterized by deceptive practices where companies overstate or misrepresent their environmental or social performance to appear more sustainable than they are. Ethical ESG reporting, by contrast, entails full, accurate, and transparent disclosure of material information that reflects a company's genuine sustainability impact. Research by Lyon and Montgomery (2015) defines greenwashing as the gap between environmental communication and actual performance, driven by reputational incentives and weak oversight. Meanwhile, Hahn and Lülfs (2014) point out that ethical ESG reporting requires addressing both positive and negative sustainability impacts, embracing transparency even when outcomes are unfavorable. As ESG expectations rise among investors and regulators, distinguishing between greenwashing and ethical conduct becomes a central task for accountants, who are ethically and professionally obligated to uphold the credibility of sustainability disclosures.

## **2.4. Justification for a hybrid approach (e.g., combining ethics with sustainability accounting frameworks)**

Given the complexity and multidimensionality of ESG disclosures, a hybrid theoretical approach that integrates ethical theories with sustainability accounting frameworks offers a more holistic understanding of reporting behavior. For instance, Bebbington and Larrinaga (2014) argue for a critical sustainability accounting perspective that incorporates ethical reasoning, stakeholder inclusivity, and environmental accountability into performance measurement systems. Such a hybrid model allows for both normative assessment (what should be disclosed and why) and technical evaluation (how disclosures are structured and assured). Gray (2010) similarly advocates for integrating moral imperatives into the construction of accounting systems, arguing that without ethical considerations, sustainability reporting risks becoming a performative rather than transformative practice. This integrative approach provides a robust foundation for accountants to engage meaningfully with ESG data, ensuring that financial disclosures are not only compliant but also ethically sound and socially responsible.

# **3. Literature Review**

## **3.1. ESG reporting standards and their ethical implications**

The emergence of comprehensive ESG reporting standards has significantly transformed corporate transparency and accountability. Christensen, Hail, and Leuz (2021) argue that mandatory ESG

reporting enhances information quality and reduces greenwashing by providing clearer guidance on what and how to disclose. Their analysis suggests that consistent global standards, like those proposed by the IFRS Foundation, may improve capital market efficiency by aligning ESG disclosures with investor expectations. Ethical implications emerge particularly when firms use vague or boilerplate language to fulfill requirements without genuine behavioral change.

Similarly, Szöke et al. (2021) examine the ethical dimensions of ESG reporting in the context of stakeholder theory. They conclude that companies often face tension between disclosing negative environmental impacts and maintaining a positive public image. This can lead to strategic omissions or manipulations in sustainability reports. The ethical burden, they argue, lies not only in what is reported but in how the reporting affects stakeholder trust and decision-making.

### **3.2. Role of accountants in sustainability disclosures**

The role of accountants has expanded from financial stewardship to active participation in sustainability and ESG reporting. Al-Shaer and Zaman (2020) emphasize that accountants are now responsible for integrating financial and non-financial information, especially in assurance functions. Their findings indicate that the quality of ESG reporting improves when sustainability assurance is conducted by accounting professionals, due to their adherence to professional ethical standards.

Furthermore, Parker (2020) explores how accountants are reshaping corporate sustainability by embedding ESG into mainstream accounting systems. He notes that accountants increasingly influence ESG strategy, metrics selection, and performance management, not just reporting. Their technical expertise and ethical obligations position them as key agents in aligning financial reporting with long-term environmental and social outcomes.

### **3.3. Greenwashing: motives, detection, and consequences**

Greenwashing has been identified as a major ethical challenge in ESG reporting. Lyon and Montgomery (2021) define it as the gap between environmental claims and actual firm behavior, often driven by reputational motives or regulatory arbitrage. They emphasize the strategic nature of greenwashing and warn that without external assurance, ESG disclosures can become vehicles for misinformation.

Boiral, Heras-Saizarbitoria, and Brotherton (2020) propose a framework for detecting greenwashing by assessing inconsistencies between disclosed data and third-party verified performance indicators. They argue that detection requires a combination of qualitative content analysis and quantitative ESG performance benchmarking. The consequences of unchecked greenwashing include reputational damage, stakeholder mistrust, and regulatory sanctions.

### **3.4. Review of regulatory frameworks (EU CSRD, SEC ESG rules, ISSB standards)**

The EU's Corporate Sustainability Reporting Directive (CSRD) represents a shift from voluntary to mandatory ESG reporting. Capelle-Blancard and Petit (2023) argue that the CSRD's "double materiality" concept obliges firms to consider both financial and non-financial impacts, thus enhancing ethical accountability. They note, however, that implementation challenges remain, especially for SMEs and firms operating across jurisdictions with less developed regulatory infrastructure.

Meanwhile, the ISSB (International Sustainability Standards Board) and SEC (Securities and Exchange Commission) have also introduced frameworks aiming to standardize ESG disclosures globally. KPMG (2023) highlights how IFRS S1 and S2 standards under ISSB focus on climate-related disclosures aligned with TCFD recommendations. These frameworks aim to improve consistency and comparability across industries but still face criticism for underrepresenting social and governance metrics.

## 4. Methodology

The research compiles a detailed record of 60 significant greenwashing incidents, with 40 cases stemming from the United States and another 20 from Europe. These cases spotlight companies that have struggled with maintaining credible ESG (Environmental, Social, and Governance) reputations. Each incident is meticulously documented through various sources, including lawsuits, financial penalties, regulatory enforcement actions, and thorough investigations conducted by academics and media outlets.

Furthermore, the study delves into a comparative analysis of ESG regulations and enforcement practices between the U.S. and the EU. It explores how these two regions differ in their approach to ESG compliance, identifying recurring patterns in the nature of greenwashing claims and the typical responses from regulatory authorities on both sides of the Atlantic.

## 5. Comparative results

### 5.1. Synthesis of Findings: Diverging Regulatory Approaches to Greenwashing

The comparative examination of U.S. and EU ESG enforcement mechanisms underscores a fundamental divergence in regulatory philosophy and execution. The EU's stringent, legally binding instruments—such as the Corporate Sustainability Reporting Directive (CSRD) and Sustainable Finance Disclosure Regulation (SFDR)—have institutionalized sustainability reporting, mandating external assurance and adherence to a sophisticated taxonomy framework. This structured environment fosters a preventive approach to greenwashing, emphasizing accountability through compliance.

In contrast, the U.S. lacks a cohesive, mandatory ESG disclosure regime, resulting in a reactive enforcement model. Regulatory scrutiny often arises *ex post facto* through litigation or public exposure rather than embedded governance processes. The absence of standardized definitions and obligatory audits allows for significant discretion in ESG representations, increasing the risk of inconsistent disclosures and ethical lapses.

This synthesis of findings reveals that while the EU is advancing towards a formalized, regulated ESG assurance landscape, the U.S. remains fragmented, relying heavily on market and societal pressures to induce transparency.

### 5.2. Ethical Tension Points and the Accountant's Role as Moral Agent

Amidst this evolving regulatory environment, accountants are increasingly positioned as moral agents navigating complex ethical landscapes. In jurisdictions with ambiguous ESG mandates, such as the U.S., accountants face acute ethical tension points—balancing fiduciary duties to clients with societal expectations for truthful and responsible sustainability reporting. The discretion afforded by loosely defined ESG criteria can pressure accountants to engage in, or tacitly endorse, selective disclosures that may border on greenwashing.

Even in the EU's more codified framework, ethical dilemmas persist, particularly in the interpretation and application of taxonomy classifications and technical screening criteria. Accountants must exercise professional judgment beyond mere compliance, ensuring that sustainability claims withstand ethical scrutiny and reflect substantive corporate actions.

Thus, the accountant's role transcends technical assurance, evolving into that of an ethical gatekeeper who mediates between corporate narratives and the broader societal imperative for integrity and transparency in ESG disclosures.

### 5.3. Strategic Implications for Corporate Governance and Accounting Education

The findings carry profound strategic implications for corporate governance structures. Boards of directors must expand their oversight capacities to encompass ESG considerations, fostering a governance culture where sustainability is embedded into strategic decision-making. This shift necessitates that governance bodies acquire ESG fluency, enabling them to critically evaluate non-financial disclosures and their alignment with corporate strategy and societal expectations.

Parallelly, accounting education must undergo a fundamental transformation. Traditional curricula focusing predominantly on financial metrics are insufficient for preparing professionals to navigate the multifaceted challenges of ESG reporting. Educational institutions must integrate interdisciplinary modules encompassing sustainability accounting, ethical decision-making, and digital assurance technologies. This holistic approach will cultivate a new generation of accountants who are not only technically proficient but also ethically grounded and strategically aware.

### 5.4. Future Directions: Ethics-by-Design in ESG Reporting Systems

Looking forward, embedding “ethics-by-design” into ESG reporting systems offers a robust pathway to institutionalizing integrity within corporate disclosures. This concept advocates for the proactive incorporation of ethical principles—such as transparency, accountability, and stakeholder inclusiveness—into the very architecture of reporting frameworks.

Technological advancements can serve as enablers of this paradigm. Blockchain technologies can ensure immutable audit trails for sustainability data, while AI-driven analytics can enhance the detection of anomalies and inconsistencies. However, technology alone is insufficient; ethical considerations must be codified at the policy-making level to ensure that regulatory expectations are harmonized globally.

For accountants, this evolution demands a dual proficiency: technical acumen in emerging assurance technologies and ethical leadership capable of guiding organizations in adopting integrity-centric reporting practices. As custodians of trustworthy information, accountants will be pivotal in designing and auditing ESG systems that are not only compliant but intrinsically aligned with societal values and sustainable development goals.

## 6. Conclusions

This study advances the discourse on ethical accounting within ESG-driven strategic decision-making by presenting an integrated analysis that bridges regulatory frameworks, corporate governance, and professional ethics. One of its principal contributions is the comparative exploration of the United States and European Union's approaches to ESG disclosures, highlighting how variations in legal mandates, enforcement rigor, and assurance practices shape the reliability and credibility of sustainability reporting. The analysis of prominent greenwashing incidents serves not merely as case evidence but as a lens through which the systemic weaknesses of voluntary reporting and fragmented regulations are exposed.

A critical theoretical contribution of this research lies in reframing the accountant's role from a mere compliance officer to an active moral agent. In this capacity, accountants are positioned as gatekeepers of ethical conduct, bearing the responsibility to challenge corporate narratives that prioritize optics over substance. This repositioning of the accounting profession aligns with evolving stakeholder expectations that demand authenticity, transparency, and accountability in sustainability practices.

The study further emphasizes the strategic necessity of embedding ESG literacy within both corporate governance structures and accounting education curricula. It argues for a pedagogical shift that

integrates ethical reasoning, critical evaluation of ESG claims, and a robust understanding of sustainability metrics as core competencies for future accountants. Lastly, by proposing an ethics-by-design framework for ESG reporting systems, the research lays foundational groundwork for developing technological and procedural solutions that inherently prioritize ethical integrity, thus preemptively mitigating the risk of greenwashing.

The findings of this research bear significant implications for both policymakers and the accounting profession. A central policy recommendation is the need for greater international harmonization of ESG disclosure standards. The current regulatory patchwork creates opportunities for regulatory arbitrage, undermining efforts to establish a coherent global sustainability reporting framework. Aligning disclosure requirements, while respecting jurisdictional nuances, would not only enhance comparability but also fortify the global financial system's capacity to address sustainability risks.

From a professional practice perspective, the study underscores the urgency of making independent assurance engagements mandatory for ESG disclosures. The European Union's CSRD and taxonomy regulations, with their legally binding nature and mandatory audit requirements, provide a robust model that could be instructive for jurisdictions grappling with the credibility gap in voluntary ESG reporting. In contrast, the U.S. landscape, characterized by fragmented and largely voluntary assurance practices, reveals vulnerabilities that compromise the reliability of sustainability information and erode stakeholder trust.

Moreover, this research calls upon accounting bodies and professional organizations to champion a redefinition of the accountant's role, embracing a broader ethical mandate. Accounting firms must cultivate a professional ethos that prioritizes ethical stewardship, ensuring that sustainability assurance is not treated as a perfunctory compliance exercise but as a critical function that upholds public trust and corporate accountability.

Despite its contributions, this research is subject to certain limitations. The comparative analysis is primarily based on publicly available regulatory documents, legal proceedings, and media-reported cases of greenwashing, which, while illustrative, may not fully capture the nuanced, industry-specific practices and internal corporate dynamics influencing ESG disclosures. Furthermore, as ESG regulatory landscapes are rapidly evolving—particularly in the U.S.—some observations may become outdated as new policies are enacted or existing frameworks are refined.

Another limitation stems from the reliance on secondary data sources, which, despite their credibility, may lack insights into the lived experiences and ethical dilemmas faced by professionals directly involved in ESG assurance processes. Consequently, there remains a gap in understanding how accountants navigate the tension between organizational pressures and their ethical obligations as assurance providers.

Future research could address these limitations through qualitative studies involving in-depth interviews with key stakeholders, including auditors, corporate sustainability officers, regulators, and investors, to explore the practical challenges and ethical decision-making processes in ESG assurance. Longitudinal research tracking the implementation of mandatory assurance practices and their impact on reporting quality and corporate behavior would also offer valuable insights. Additionally, further investigation into the integration of emerging technologies—such as blockchain-enabled ESG reporting and AI-driven audit analytics—within an ethics-by-design framework presents a fertile ground for advancing both academic theory and professional practice.

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## **New sustainability report: case study on the electricity sector**

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### **Abstract**

The growing demand from stakeholders for companies to disclose non-financial information has led international organizations to intervene in order to establish minimum standards for the disclosure of this information, even though this may be voluntary.

In order to meet the current challenges, various international organizations have developed frameworks that establish disclosure standards. The Global Reporting Initiative (GRI) framework currently represents the best global practices for reporting economic, environmental and social information. It is, therefore, considered a world leader in providing sustainability reporting standards. However, this framework does not cover all the current requirements, leading other organizations, such as the European Financial Reporting Advisory Group (EFRAG) and the International Sustainability Standards Board (ISSB), to publish their frameworks, albeit based on the GRI standards.

With the recent release of these disclosure standards by EFRAG and the ISSB, it has become necessary for the various economic agents to assess their usefulness and identify the changes and compliance costs of switching to the new benchmarks, which are more orientated towards the current Environmental, Social and Governance (ESG) aspect than the initial models.

This research project is a case study of an interpretative and qualitative nature. Its main objective is to analyze the applicability of the requirements and demands of the ISSB standards (IFRS S1 and IFRS S2) and the European Sustainability Reporting Standards (ESRS) in the Integrated Report of a company in the electricity sector based on the economic year 2022. The aim is to compare the current report, which is based on the GRI framework, with its publication based on the new frameworks, assessing the main differences and their impact on the report of the entity analyzed.

Regarding the comparison of GRI standards with ESRS standards, our analysis shows that these are fully aligned with GRI standards (GRI, 2022). For companies operating in the EU, the CSRD reinforces and increases the relevance of the GRI standards since most EU companies already report according to the GRI standards, and the alignment of these two standards will better prepare these companies for the ESRS standards (GRI, 2022). ESRS standards require companies to report all information that is materially relevant, as well as risks or opportunities (GRI, 2022). It is worth noting that if the ESRS standards do not address certain topics, companies must use the GRI standards to disclose this type of information in their report (GRI, 2022). It can be stated that GRI standards and ESRS standards can be applied complementarily. However, the EU reminds us that companies must avoid duplication of work at all costs. At the same time, the IFRS Foundation, EFRAG and GRI are working together to achieve reliable, comparable, and robust standards that help in the value-creation process (GRI, 2022).

Finally, regarding the comparison of ISSB standards with ESRS standards, it is worth highlighting the strong international adherence of several renowned organizations, such as IOSCO, the G20, the G7 and the Financial Stability Board, to ISSB standards. It should also be noted that the ISSB standards are part of the IFRS Foundation, meaning that they are based on other investor-focused standards and frameworks such as Integrated Reporting, the SASB Foundation and the Climate

Disclosure Standards Board, which are an integral part of the IFRS Foundation, as well as the recommendations of the Task-Force on Climate-Related Financial Disclosures.

Regarding the scope of ISSB standards, they use the terminology for profit-oriented companies, including public sector business entities. Furthermore, ISSB standards cover sustainability-related issues in general through IFRS S1 and climate-related issues through IFRS S2, in contrast to ESRS standards that cover environmental, social and governance topics through the twelve ESRS standards (Hennaux, 2023). ISSB standards were developed to meet the needs of investors, lenders and creditors, while ESRS standards were developed to meet the needs of a broad group of stakeholders. Interoperability between the two standards has been a concern for companies and regulators. Both EFRAG and ISSB maintained a constant dialogue during the development of their standards to ensure the closest possible alignment, and they decided to base their structural approach on the same existing framework. Both sets of standards use the framework developed by the TCFD and go further by adding more requirements to ensure a higher level of thoroughness. The ISSB and ESRS are also aligned on key concepts and business practices that require information about companies' value chains. Although the two standards seek to align the two standards, there are still some differences that need to be explained, namely the issue of materiality. According to ISSB standards, materiality is based on financial materiality; on the other hand, ESRS standards follow the concept of double materiality, that is, materiality is not only governed by financial issues but must also take into account sustainability issues, that is, the company's impact on sustainability. Another difference to highlight between ISSB standards and Directive 2022/2464 concerns legal issues since ESRS standards are based on EU legal requirements, which, on the one hand, are seen as an advantage for EU companies and, on the other hand, seen as a disadvantage for companies operating outside the EU.

All requirements of IFRS S2 for climate-related disclosures can be found in ESRS E1 Climate Change. Furthermore, ESRS E1 requires more information and detail in all four reporting areas (governance, strategy, impact risks and opportunities, and metrics and objectives). While ESRS standards are based on CSRD, a directive developed by the EU, ISSB standards were developed by an international organization that has no regulatory power.

Finally, it can be argued that full interoperability between the two standards is unlikely, given the specific links of the ESRS with other EU laws, its inclusion in a broader set of stakeholders and its materiality approach. However, the ISSB and EU bodies are continuously working to improve interoperability; EFRAG that the ESRS were designed so that compliance with the ESRS will mean compliance with the ISSB standards.

In conclusion, it can be said that GRI standards are interoperable with ISSB standards and ESRS standards. However, these should not be used together. Therefore, in general, companies in the EU are expected to adopt ESRS standards, as they are more demanding and comprehensive in nature. For companies covered by the CSRD, it will be necessary to adopt the ESRS standards, as these have been updated by the European Commission. Therefore, it is not expected that ISSB standards will have a significant influence in Europe since these standards, in their general points, are coordinated and fulfil the same dissemination objective.

## **Toward sustainable forest management in Portugal: integrating biomass energy, fire prevention, and economic development**

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### **Abstract**

Although Portugal remains heavily reliant on oil imports to meet its energy demands, the past decade has witnessed substantial progress in the adoption of renewable energy sources, particularly hydroelectric, solar, and wind power. To further diversify its renewable energy portfolio, the Portuguese government approved the construction of four additional forest biomass thermal power plants in 2017. This expansion was considered promising since forests cover approximately one-third of the national territory. By 2024, electricity generation from forest biomass accounted for 6% of the total renewable energy production in Portugal.

The revision of the Renewable Energy Directive (RED III), adopted on 23 September 2023, reinforces the commitment of EU Member States to increase the share of gross final energy consumption from renewable sources - from the previous target of 32% to 42.5% by 2030. While the directive acknowledges biomass as a key renewable energy source, it simultaneously eliminates incentives for electricity generation from forest biomass when waste heat is not recovered, thus shifting the focus toward more efficient cogeneration systems.

A major challenge for forest biomass valorization in Portugal stems from demographic and socio-economic changes. The continued depopulation and ageing of communities in forest-dominated areas, most of which are privately owned, has led to the abandonment of traditional land-use practices. Biomass is no longer utilized as a primary source of energy or soil amendment, contributing to widespread neglect of forest lands. This, in turn, has increased fuel accumulation and heightened the frequency and severity of forest fires. The situation is particularly critical in the wildland-urban interface, where poor land management and climate change-induced stress have significantly increased wildfire risks.

In response to these challenges, government initiatives have focused on the development of sustainable forest management strategies through policy reforms and public engagement. Legislative measures have emphasized the importance of preserving genetic diversity, maintaining forest carbon stocks, and safeguarding communities in high-risk areas through enhanced fire prevention and resilience planning.

The management of residual forest biomass remains complex due to the limited economic viability of direct combustion technologies. Portugal generates an estimated 1.7 to 2.5 million dry metric tons of forestry residues annually, largely from eucalyptus and maritime pine stands. The valorization of this biomass is particularly relevant in Mediterranean and southern European regions, where forested landscapes and high summer temperatures make these areas especially vulnerable to large-scale wildfires. Biomass utilization in such contexts supports climate goals by contributing to carbon neutrality, increasing the diversity of renewable energy sources, and mitigating fire risk through fuel load reduction.

This study investigates technological pathways for the energy recovery of residual biomass, emphasizing the role of supportive public policies in creating economic incentives and enhancing fire resilience. Using a roadmap methodology, the research evaluates current trends and conducts a SWOT analysis of various biomass valorization scenarios. The economic significance and governance of forest resources are further examined within the framework of a circular economy, highlighting the intersection between sustainable energy production, climate adaptation, and forest fire prevention.

**Keywords:** *Forest Waste, Biogas, Wildfires, Renewable Energy, Sustainability*

# **The role of big data in transforming logistics services: opportunities and challenges. A literature review**

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## **Abstract**

This study explores how big data analytics (BDA) is reshaping logistics services by enhancing operational efficiency, predictive capability, and strategic agility. The objective of this paper is to critically examine both the benefits and challenges of adopting big data in logistics and illuminate how it facilitates the digital transformation of supply chains. The study integrates various real-life case studies with a thorough literature review for effective analysis. Recent studies are synthesized to develop a multi-dimensional view on the integration of BDA technologies such as IoT, RFID and AI in the logistics systems. Case studies from companies like Amazon, DHL, and Maersk are used to illustrate the practical implications of these technologies. The findings suggest that big data can be useful to forecasting, asset utilization, routing and customer responses. However, implementation is often hampered by lack of unified IT systems, high cost of infrastructure, data privacy concerns, and qualified professional. Widespread adoption is hindered by ethical issues like algorithmic bias and surveillance. This paper contributes to the academic discourse by providing an overview of the application of Big Data in logistics. It combines theoretical concepts with the practical application of Big Data in the logistics industry. It also highlights some tensions that remain unresolved and directions for future research on sustainable and responsible logistics innovation.

**Keywords:** *big data, logistics services, predictive analytics, RFID, supply chain*

## **1. Introduction**

Across the globe, trade networks open-up more and digital technology advances further, logistics services have become an essential driver of economic growth, supply chain resilience, and competitiveness. The emergence of big data characterized by immense volume, rapid velocity, wide variety, questionable veracity, and potential value has revolutionized the ways in which logistics operations are designed, managed, and optimized (Gandomi & Haider, 2015). Increasing pressures from globalization, rising customer expectations and accelerating e-commerce are forcing logistics providers to adopt big data analytics (BDA) to enhance forecasting, efficiency, responsiveness and decision-making in real-time (Waller & Fawcett, 2013). Nowadays, data streams come from a broad spectrum of sources across the logistics value chain: GPS trackers, RFID sensors, IoT devices, enterprise resource planning systems, etc. (Marr, 2016). The value of this data lies in its conversion into actionable insights using advanced analytics, artificial intelligence, and machine learning, which can predict demand patterns, reduce operational costs, and improve resource utilization (Wamba et al., 2017). Leading companies such as Amazon and DHL exemplify the transformative potential of big data by utilizing real-time tracking, dynamic routing, and predictive inventory management as competitive differentiators. Big data is, an enabler of operational improvements and value-added

services. For example, companies can offer different logistics options, such as faster delivery, carbon-neutral shipping, and proactive problem-solving, by combining customer analytics into more sophisticated segmentation.

These capabilities not only improve customer satisfaction but also serve as differentiators in competitive markets where service customization is becoming the norm. In addition, logistics companies are experimenting with blockchain technologies to fabricate unchangeable transparent records of shipping events which can, when coupled with big data analytics, enhance trust and traceability within intricate global supply chains. However, the adoption of big data in logistics is not without its obstacles. Organizations face substantial challenges including poor data integration across fragmented systems, limited technological infrastructure, data privacy risks, and a shortage of skilled personnel capable of interpreting complex data models (Tan et al., 2015). Moreover, ethical concerns surrounding data ownership, surveillance, and algorithmic bias necessitate the development of governance frameworks to ensure responsible data use in logistics ecosystems. This study, critically examines the role of big data in transforming logistics services, identifies key opportunities for performance enhancement and innovation, and explores the technical, organizational, and ethical challenges associated with its adoption. Through a review of contemporary literature and practical cases, this research offers insights into how logistics companies can strategically harness big data while navigating the complexities of its implementation.

## 2. Literature Review

The last decade has seen substantial change in the logistics sector due to the rise of big data technologies. There has been a notable scholarly emphasis on how big data analytics (BDA) improves and optimizes logistical processes, allowing for more precise automation of transportation, warehousing, and inventory control (Wamba et al., 2015). This shift, in particular, is not a mere technological improvement; it signifies a change in a logistics system's structure from a cost system towards a value system focused on speed, precision, customer satisfaction, and service. A foundational study by Wang et al. (2016) articulated the importance of BDA in logistics by identifying key capabilities such as data integration, analytics, and real-time decision support. These capabilities are seen as essential enablers of predictive maintenance, inventory optimization, and capacity planning. Building on this, Talwar et al. (2021) conducted a systematic literature review that emphasized the convergence between big data, artificial intelligence, and smart logistics infrastructure. Their work highlighted how organizations use BDA to drive cost reduction, improve delivery accuracy, and foster customer-centricity. Recent literature, (da Silva, Federio and Garza-Reyes et l.,2023) investigated the predictive analytics and real-time monitoring used by logistics service providers in relation to how they adapt to a disruptive environment. Their conclusions highlight the further need for supply chain agility and resilience, areas where big data has been particularly useful. Similarly, Jahani, Jain, and Ivanov (2023) offered a meta-level analysis of the methodologies employed in big data logistics research. Their study indicated an increasing reliance on hybrid models that incorporate machine learning, simulation, and optimization techniques to enhance decision-making precision. They also identified that while the volume of publications in this area has surged, methodological diversity and practical implementation strategies are still evolving. Other studies have also contributed focusing on organizational learning and proactive adaptability regarding the success of adopting big data analytics. For instance, Singh and Arya (2022) posit that companies willing to make investments towards upgrading organizational learning systems and nurturing an active experimentation culture tend to maximize value from big data endeavors. This dynamic capability view provides a framework to explain why some organizations are able to maintain a competitive edge through data-related initiatives while others struggle, despite having similar technologies, in the market. Note that socio-technical interaction within big data systems is

another evolving domain of research. It has been noted by Pereira et. al (2023) that BDA is dependent on more resources than algorithms and infrastructure. It also involves how end-users make sense of the value and take action on their insights. This further complements the argument that the implementation of big data requires attention to people and their activities within the system. The issues posed with the application of BDA have been relayed as an ongoing concern. Moldagulova and Satybaldiyeva (2020) pointed out the gap in the technological ability to implement the tools, which is particularly more severe in the Global South. These authors argue that there is a lack of appropriate infrastructure, such advanced technologies, high costs of implementation, and a shortage of skilled workers. Even more advanced economies have BDA, and Jin and Kim (2018) offered a perspective that provided culturally and strategically disconnects impeded BDA integration. Other research adds to the argument of big data application in selected logistical domains. Chaudhuri et al. (2018) aptly demonstrated use of BDA in cold chain logistics where real time monitoring has significantly reduced loss and increased compliance.

Likewise, Barbosa et al. (2018) highlighted how analytics enhance resource allocation and visibility within distribution networks, with real cost and service gains. Paluri and Pawar (2022) identified a persistent gap between academic knowledge and industry adoption. While academic models demonstrate the theoretical benefits of BDA, practical implementation often lags due to regulatory constraints and fragmented supply chain data systems. This disjunction is echoed by Winkelhaus and Grosse (2020), who called for standardized data protocols, collaborative platforms, and integrated IT strategies to maximize big data's utility in logistics.

Across all studies, a recurring theme is the **strategic potential** of big data to transform logistics from a reactive cost center to a predictive, value-generating function. However, to achieve this transformation, scholars emphasize the need for interdisciplinary research, cross-sector collaboration, and capacity building within logistics organizations (Wamba et al., 2015; Wang et al., 2016; Jahani et al., 2023). In conclusion, the literature provides robust evidence that big data significantly enhances logistics efficiency, adaptability, and innovation. Yet, it also underscores critical challenges in implementation, ethics, and technological integration. Future research should focus on developing agile analytics frameworks, exploring cross-border logistics data governance, and assessing the long-term sustainability impacts of BDA in global logistics.

### 3. Implementations and case studies

The practical application of big data in logistics services has been extensively documented through empirical studies and case analyses. These applications span key logistics activities such as transportation management, inventory forecasting, warehouse automation, and last-mile delivery optimization. The cases collectively demonstrate how logistics companies harness big data to improve agility, operational efficiency, and customer responsiveness.

One of the most cited success stories is Amazon, which uses real-time analytics and machine learning to drive its fulfillment processes. Amazon relies on proprietary machine learning systems to run their logistics which takes for advantage of enormous datasets from user interaction, delivery timings and performance, and external factors like weather or traffic (Marr, 2016). Their anticipatory shipping model relied on historical purchasing behavior to ship product to likely destinations before the customer makes an order, accordingly decreasing order delivery windows even further (Waller & Fawcett, 2013). DHL, a global logistics provider has leveraged big data through various initiatives. The “Resilience360” platform pulls data from numerous sources to anticipate disruptions and to reroute shipments before disruptions occur. The “Smart Truck” integrates data on traffic in conjunction with delivery parcel loads and reroutes deliveries accordingly, helping to minimize fuel consumption and emissions from delivery trucks (Barczak et al., 2023). One of the most detailed examples of big data application in maritime logistics comes from **Maersk**, the world’s largest

container shipping company. Maersk has invested heavily in digital infrastructure to support data-driven decision-making across its global operations. A key component of this strategy is the integration of **RFID technology** into its container logistics network. The company uses RFID sensors alongside GPS and IoT devices in its **Remote Container Management (RCM)** system to monitor temperature, humidity, and location of refrigerated containers commonly referred to as "reefers" in real time (Paluri & Pawar, 2022). The RFID-enabled containers are embedded with sensors that transmit telemetry data to centralized platforms, allowing Maersk's control centers to identify potential problems such as temperature deviations or equipment malfunctions before they impact cargo. For instance, if a reefer carrying pharmaceuticals shows signs of temperature drift, Maersk operators receive automated alerts via the RCM dashboard, enabling them to reroute the shipment, notify stakeholders, or dispatch maintenance instructions immediately. This ensures **compliance with stringent cold chain requirements** and enhances customer satisfaction by minimizing product spoilage or delays. Moreover, RFID tags contribute to **automated check-in/check-out processes** at Maersk-operated terminals, reducing dwell times and paperwork. These tags also support asset tracking, container inventory optimization, and predictive maintenance by generating historical usage data. As a result, Maersk not only enhances the transparency and responsiveness of its logistics services but also strengthens its ability to perform **data-driven fleet and capacity planning** (Wang & Zhang, 2022). The Maersk case exemplifies how traditional shipping firms are evolving into **digital logistics platforms**, using big data tools such as RFID to drive operational visibility, reduce risk, and optimize customer experience. It also illustrates the convergence of hardware (RFID devices), software (predictive analytics), and strategy (end-to-end visibility) in next-generation logistics ecosystems. Another pertinent case is UPS which has developed its ORION (On-Road Integrated Optimization and Navigation) system that can evaluate billions of routing permutations each day for most efficient route to improve delivery time. As reported by the company, ORION has contributed to conservation of millions of gallons of fuel in a year, and has achieved a reduction in carbon emissions. Additionally, the company has implemented predictive analytics that can help predict maintenance needs for its fleet and reduce unexpected downtimes and repair costs. Likewise, FedEx has used sensor-based logistics to provide full end-to-end visibility into high-value shipments (medical supplies, electronics, etc.). The Sense Aware platform supports real-time information about a shipment's location, temperature, humidity, and exposure to light so that its clients have extensive visibility and tools to mitigate risk. Two other relevant examples are JD Logistics and SF Express, which are in China, have used AI and RFID to create highly automated warehouses that help optimize picking and dispatch operations. In India, the logistics start-up Rivigo has taken big data and created driver relay models that improve speed while creating a better welfare model for drivers (Sharma & Sheoran, 2023). All of these examples reveal a consistent pattern; when properly used, analytics using big data can help improve visibility, responsiveness, and sustainability for logistics. However, those successes result from proper strategy, appropriate infrastructure, and organizational suitability.

#### 4. Challenges and ethical issues

While big data has introduced unprecedented opportunities in logistics services, its implementation and governance are fraught with challenges. These span technological, organizational, and ethical dimensions, often impeding the full-scale adoption of big data analytics (BDA) in logistics ecosystems. One of the primary barriers is related to data integration. Logistics networks are often made up of several stakeholders that are utilizing a different system that is not compatible. Legacy systems lead to fragmented data that makes it difficult to share and analyze data in real-time (Wang et al., 2016). Small and medium-sized logistics enterprises (SMEs) face additional challenges such as budget restrictions and limited access to cloud-based solutions and Artificial Intelligence (Moldagulova & Satybaldiyeva, 2020). In addition, the shortage of skilled professionals who can

manage data pipelines, interpret analytics results, and integrate insights into business strategy further hampers organizational transformation (Barczak et al., 2023).

On the topic of data security, the use of personally identifiable information to route packages and make deliveries raises significant ethical concerns. Data breaches related to customer data or operational systems may breach trust and also expose companies to regulatory and agency penalties (Jin & Kim, 2018). Cyberspace is becoming more digitized as logistics infrastructure is digitized; however digitization of this infrastructure may create opportunities for cyberattacks therefore there are robust demand for encryption, threat detection, and access controls (Zhang et al., 2021). The environmental impact of big data infrastructures has been an area of oversight in primary literature. As logistics companies increase their reliance on cloud services, data lakes, and live analytics platforms, the energy consumed and to an extent carbon emissions, to run data centers and to use their services is not insignificant. With companies increasingly claiming they are "sustainable", the issue of "green computing" practices and carbon offsetting activities is now reaching logistics companies. On a parallel, the use of big data also raises important ethical questions about various forms of monitoring and surveillance related to labor are coming to light. Discussing about wearable sensors and tracking devices can help to improve efficiency and may contribute to workplace surveillance systems or be a source of high-pressure labor organization (e.g., wearables to track activity through the warehouse). These dilemmas require appropriate technical mitigations but would also benefit from a more inclusive governance model that counterbalances productivity expectations with respect for dignity. Furthermore, algorithmic accountability is a growing area of regulatory scrutiny that would also apply to the logistics sector. As logistics decisions are being automated or semi-automated (e.g., assigning drivers to deliveries, deciding delivery priorities, and scheduling tasks in a warehouse) persuade and the logistics information technology undergoes many small powerful changes, the demand for transparent explainable AI is increased. Studies (e.g., Binns et al., 2022) have suggested that as logistics companies begin to adopt AI platforms to augment decision activities "that they should have an algorithmic impact assessment similar to environmental assessments that identify if and where they may introduce harm or bias. In a nutshell, organizational culture and change management remain persistent challenges.

## 5. Conclusions

Big data has emerged as a transformative force in logistics services, enabling companies to move from reactive to proactive operations. This study has explored the strategic role of big data analytics (BDA) in optimizing logistics functions, reviewed contemporary literature, examined real-world applications, and analyzed implementation challenges and ethical concerns. Empirical case studies of Amazon, DHL, Maersk, and others illustrate how big data enables real-time decision-making, enhances forecasting accuracy, and improves customer responsiveness. At the same time, the research emphasizes that widespread adoption of BDA requires overcoming significant technological, organizational, and regulatory barriers. This study contributes to academic discourse by offering an integrative, multi-dimensional analysis of big data's impact on logistics services, an area that, while growing in relevance, remains fragmented in existing research. In addition, bridges empirical industry practices with theoretical constructs from operations management, data science, and ethics. By synthesizing insights from recent studies and aligning them with classic frameworks, the study advances understanding of how logistics companies can strategically implement big data analytics to achieve competitive advantage. This study adopts a holistic approach, addressing operational applications, methodological diversity, ethical risk, and infrastructure gaps. This positions of the study as a valuable reference for scholars seeking to extend theory in areas such as smart logistics, algorithmic accountability, and digital supply chain governance.

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# **The role of financial literacy in small and medium-sized enterprises: a systematic review of the literature**

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## **Abstract**

This systematic literature review explores the role of financial literacy in small and medium enterprises (SMEs) over the past twenty-five years. Based on fourteen high-quality research articles selected through the PRISMA protocol, the study examines the scope, methodologies, thematic focus and key findings of the relevant literature. The review highlights significant variations in levels of financial literacy, influenced by demographic, social and geographical factors. According to this systematic review, financial literacy emerges as a critical factor in improving access to finance, reducing the disincentive to borrow, enhancing financial decision-making and strengthening strategic partnerships. The findings indicate that high level of financial literacy is associated with low leverage, addresses information asymmetry, enhances risk management, promotes innovation and facilitates the internationalization of firms. Government support and digital financial literacy further enhance the sustainability of SMEs and promote responsible and sustainable economic behavior. Important research gaps are identified, particularly the limited understanding of how financial literacy is associated with business sustainability, innovation, and organizational effectiveness, highlighting the need for future studies.

**Keywords:** *Financial literacy, financial knowledge, small and medium enterprises, SMEs, systematic literature review.*

# Comparative analysis of the proposals of tax reform in Greece

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## Abstract

The research thoroughly analyzes the main objectives and proposals for a modern tax system in Greece. With a view to fair distribution of the tax burden, cash efficiency and cost-effectiveness, concrete proposals are presented for the reform of the existing tax framework. To effectively tackle tax evasion, a comprehensive framework of measures is proposed, including the reduction of tax rates, the introduction of an effective system of sanctions, the assessment of existing tax exemptions and the simplification of tax legislation. From the comparative analysis of the proposals submitted by various committees, scientific bodies and professional associations, important common points emerge that reflect the desired direction of tax reform in Greece. All the proposals converge on the need to simplify the tax system, both legislatively and using new technologies. There is a common thread on some key points of tax reform. Scientific studies come to a common conclusion on the gradual abolition of living presumptions, the digitalization of tax procedures, the exchange of information between institutions, and the universal use of electronic transactions. Improving the ratio between direct and indirect taxes, while broadening the tax base and effectively combating tax evasion, will help to create a fairer tax system that distributes the tax burden according to the real ability of citizens to pay.

**Keywords:** *tax evasion, tax framework, expansion of the tax base*

## 1. Introduction

Through the comparative approach of the most important committees and institutional reports, the aspirations, successes and weaknesses of the tax mechanism are highlighted. The paper highlights the need for stability, administrative efficiency and transparency in tax policy, while analyzing how European directions and institutional inadequacies determined the course of Greek reforms.

Tax policy is a fundamental pillar of the economic governance of any state, as it affects income redistribution, investment activity and fiscal balance. In the Greek case, tax policy has always been a field of continuous interventions, which often lacked strategic planning and institutional continuity. The reforms have been a crucial process in the search for a fairer, simpler and more efficient tax system, capable of meeting the needs of European integration and internal fiscal adjustment.

Tax studies are a collection of institutional interventions and proposals formulated by committees, scientific bodies and state organizations, with the common goal of rationalizing the tax system. Analyzing these reports offers a valuable tool for understanding the long-standing problems that hinder tax stability, such as over-regulation, lack of control, widespread tax evasion, and discontinuity of policy choices.

The present paper aims to:

1. Present the historical and institutional framework of the tax reforms.

2. Comparatively analyze the individual reports in terms of their targeting, methodology and results.
3. Examine the effectiveness of the proposed reforms and their impact on tax administration.
4. It draws scientific conclusions about the institutional weaknesses and the prospects for improving the Greek tax system.

The analysis follows the methodological logic of comparative political economy, focusing not only on the content of the proposals but also on their relationship with European political directions and domestic administrative structures. Finally, the thesis attempts to highlight tax reform as a social and political issue, which goes beyond the narrow limits of economic technique.

## **2. Historical and institutional framework**

Greece's tax policy in the 1990s was shaped in a context of rapid economic, political and institutional changes. The country's entry into the European Community and later into the euro area created new requirements for fiscal discipline, administrative modernization and alignment with European taxation standards. At the same time, the Greek economy had to deal with the inflation of public debt, the extensive shadow economy and the low efficiency of the tax mechanism.

The period 1990–2002 was characterized by a constant alternation of reform efforts, but these often lacked institutional continuity. Each new government attempted to reform the tax system based on its own political priorities, leading to instability of rules and legal uncertainty. This phenomenon of "legislative overproduction" has resulted in the constant alteration of the tax framework and the strengthening of tax uncertainty between citizens and businesses (Ministry of Finance, 2002).

At the institutional level, the organization of the tax administration showed a low degree of autonomy and limited computerization. Until the mid-1990s, tax services operated according to anachronistic standards, without a single information system or reliable control mechanisms. This situation reinforced corruption, bureaucracy and the low collection capacity of the state (OECD, 1997).

The pursuit of membership in Europe's Economic and Monetary Union (EMU) acted as a catalyst for reforms, as Greece was forced to adapt its fiscal policy to the Maastricht criteria. This meant gradually reducing deficits and improving fiscal efficiency. The modernization of the tax administration was linked to the development of the TAXIS information system, which was the first step towards the digitization of tax procedures and transparency in transactions (AADE, 2002).

On a social level, the tax consciousness of citizens remained low. The state's long-standing inability to ensure equal treatment and fair distribution of the burden has strengthened suspicion of the tax authority. At the same time, the extensive use of presumptions and indirect taxes mainly burdened middle and low incomes, undermining social justice and the redistributive function of taxation (Economic Chamber of Greece, 2002).

The 1990s can therefore be described as a period of the search for reform: on the one hand, well-founded and ambitious proposals were made; On the other hand, their implementation remained fragmented and insufficient. The institutional environment of the time determined the limits of the action of the committees, which attempted to combine social sensitivity with fiscal necessity. This dual pressure – between social justice and fiscal realism – runs through all the reports that are examined below.

### **3. Analysis of individual reports**

The analysis of tax reports reveals a systematic effort to modernize Greek tax policy, in line with the socio-economic developments of the time. Each committee or body that prepared a tax report promoted a different mix of objectives, proposals and methodological tools, depending on its institutional role and the political context of the period.

#### **3.1 The 1990 Commission**

The 1990 Commission was the first organized attempt at a comprehensive review of the tax system since the 1980s. Its main purpose was to modernize the tax framework and a fairer distribution of the burden. Its proposals focused on broadening the tax base, abolishing unjustified tax exemptions and simplifying the presumption system (Ministry of Finance, 1990).

The Commission underlined the need to strengthen control mechanisms and introduced for the first time the concept of tax compliance as an indicator of the effectiveness of the administration. Despite the theoretical completeness of the proposals, implementation remained limited, as there was no political continuity or institutional support for the reforms.

#### **3.2 The 1992 Proposals and the Single European Market**

With the accession of Greece to the Single European Market in 1992, the reforms acquired a clear European orientation. The proposals focused on the alignment of Greek taxation rules with Community law, in particular as regards Value Added Tax (VAT) and corporate taxation.

The main objective was to enhance competitiveness and attract investment through a more stable and transparent tax environment (European Commission, 1992). At the same time, the idea of reducing income tax rates in combination with the abolition of multiple exemptions was promoted. However, the reform has not been accompanied by a corresponding improvement in the control mechanisms, leaving effectiveness limited.

#### **3.3 The Hellenic Society for Tax Law and Fiscal Studies (1990–1997)**

The Hellenic Society of Tax Law approached tax reform from a scientific and legal perspective, emphasizing the systematization of tax law and the need to streamline the rules. The presentations focused on:

1. The revision of the tax scale based on the principle of progressivity.
2. The review of all tax exemptions.
3. The establishment of objective criteria for the calculation of the net profits of businesses.
4. The upgrading of the role of audit mechanisms through institutional training of employees (Hellenic Tax Law Society, 1997).

The contribution of the Company has been decisive in the cultivation of tax awareness and in the foundation of the perception that taxation should serve wider social purposes. However, the lack of administrative support limited the implementation of its proposals.

#### **3.4 The Georgakopoulos Commission (2002)**

The Georgakopoulos Committee, established by the Ministry of Finance in 2002, was a breakthrough in the tax reform process. For the first time, tax policy was considered as a political and economic issue and not just as an accounting adjustment. The Commission has identified three key areas for action:

- Simplification of the tax system and reduction of the multiplicity of laws.
- Strengthening transparency and trust between the state and citizens.

- Utilization of information technologies through the TAXISnet system.

The 2002 report proposed the introduction of uniform rules for the taxation of natural and legal persons, the reduction of bureaucracy and the adoption of electronic controls. Although the proposals formed the basis for subsequent improvements, such as the establishment of the Independent Authority for Public Revenue (IAPR), implementation remained partial, mainly due to political discontinuity.

### **3.5 The Economic Chamber of Greece (2002)**

In 2002, the Economic Chamber of Greece, as the state's institutional advisor on economic issues, submitted a comprehensive framework of reform proposals. Its basic principles were:

- Simplicity and stability of tax legislation.
- Fairness and progressivity in income taxation.
- Fight against tax evasion through cross-checks.
- Modernization of public services through computerization.

The Chamber pointed out that the continuous amendment of laws leads to institutional insecurity and deters investments. It also stressed that fiscal stability is a key prerequisite for macroeconomic growth and social confidence (AIF 2002).

These reports, although differing in methodology and emphasis, converge on the diagnosis of the same problems: complexity, tax evasion, administrative inefficiency and lack of institutional stability. These observations will form the basis of the comparative discussion in the next chapter.

### **3.6 International Monetary Fund (2004)**

2004 was a crucial year for the debate on tax reform in Greece, as economic conditions, the requirements of European integration and the needs for sustainable growth made it imperative to reform the tax system. In this context, two important institutional bodies, the International Monetary Fund (IMF) and the Hellenic Federation of Enterprises (SEV), submitted extensive proposals aimed at creating a simpler, more transparent, fair and developmental tax system. Their interventions had a common orientation: reducing distortions, strengthening competitiveness, combating tax evasion and stimulating entrepreneurship.

The IMF, in the context of the evaluation of Greek economic policy, submitted specific recommendations aimed at improving the efficiency and transparency of the tax system, as well as creating incentives for investment and growth. A key element of the proposal was the reduction of the corporate tax rate from 35% to 25%, applying the new rate to total profits and not only to undistributed. This measure was considered decisive competitiveness and attracting investment capital.

At the same time, the IMF proposed to increase the depreciation rates for new investments, so that they act as an effective and transparent investment incentive, encouraging technological modernization and job creation. Instead, it recommended the abolition of tax-free reserves from undistributed profits, considering that they were often misused, reducing the tax base and undermining the principle of equality in taxation.

In addition, the Fund opted for the replacement of specific deductible expenses from taxable income, with the aim of reducing the arbitrary application of tax exemptions and enhancing transparency. As far as personal income tax is concerned, it was proposed to reduce the maximum tax rate from 40% to 35-39%, to increase the tax-free limit and to introduce intermediate rates of 20% and 25%, in order to distribute the tax burden more fairly.

Another important point of the IMF's proposals concerned the improvement of the functioning of the tax administration. He suggested the introduction of tax audits every three years, based on recent returns, so that there is consistency and predictability. At the same time, it was proposed to strengthen out-of-court dispute resolution mechanisms, to reduce time-consuming court proceedings. Finally, the IMF recognized the importance of supporting small and medium-sized enterprises (SMEs), proposing an increase in grants of up to ten percentage points, in line with the institutional frameworks of the European Union, as a lever to promote entrepreneurship and employment.

### **3.7 SEV (2004)**

SEV, as a representative of the productive sector of the economy, presented an extensive program of tax reforms aimed at a system that was understandable, fair and growth oriented. Its positions were structured in thematic axes that covered almost every aspect of tax policy: from the structure of the tax mechanism to the administration of tax justice.

In the first axis, SEV pointed out that the tax system had to be simple and understandable, with clear rules and without contradictory or unclear provisions. He proposed replacing all individual taxes and fees on real estate with a single property tax, codifying legislation to avoid splitting provisions into different bills, and abolishing the Code of Books and Records, which was considered bureaucratic and outdated.

At the level of technological modernization, SEV called for the use of the TAXIS information system and the possibility of electronic cross-checking of data, as well as the use of International Accounting Standards (IAS) for the calculation of corporate tax. In this way, administrative costs would be reduced and incompatibilities with the European institutional framework would be avoided.

Regarding tax justice, SEV stressed the need for a broad tax base, which would limit the scope for tax evasion, and for low, but fair tax rates. He called for the abolition of tax advances when recourse to justice, the creation of a special body of tax judges, as well as the speedy adjudication of tax cases within three years.

Regarding the taxation of businesses, SEV proposed a framework of incentives for investment, innovation and mergers. It called for the tax equalization of listed and non-listed companies, the possibility of taxation at group level, and the recognition of expenses for services by parent foreign companies, with the aim of strengthening cross-border investment.

Another important area of SEV's proposals concerned the abolition of parafiscal taxes, which were considered anachronistic and a disincentive to economic activity. Particular reference was made to the 0.6% levy on loans under Law 128/75, which increased the cost of financing businesses compared to European ones. At the same time, the reduction of excise duties on fuel and the implementation of the European directive on tax exemption for petroleum products used in production were requested.

Finally, SEV highlighted the importance of a tax system of a developmental nature, which functions as an economic policy tool. He called for regional subsidies, strengthening research and innovation, as well as reducing taxes to levels similar to the lowest in the European Union.

### **3.8 IOBE (2004)**

The tax reform attempted in Greece in 2004 is part of a broader context of fiscal adjustment and efforts to consolidate the public sector, at a time when the Greek economy was showing signs of fatigue despite the high growth rate of previous years. The study by the Foundation for Economic and Industrial Research (IOBE) underlines that the reform took place in unfavorable domestic and international economic conditions, with rising inflation, stagnating primary surpluses and slowing growth momentum being critical pressure factors.

The country's accession to the Economic and Monetary Union (EMU) provided significant stability benefits, but at the same time limited the scope for independent monetary policy, making their fiscal management and fiscal policy pre-eminent mechanisms for macroeconomic adjustment. In this context, the Greek government was forced to increase the tax burden in order to reduce deficits, but without achieving a corresponding restraint in public spending. This choice, in conditions of a negative international situation, resulted in a further deterioration of the competitiveness of the Greek economy.

The main objective of the 2004 tax reform, as shown by the analysis of the Foundation for Economic and Industrial Research (IOBE), was to simplify the tax system without reducing total tax revenues. The reform did not seek radical changes but a restructuring of the existing structure of the system. Among the main interventions are the reduction of the number of taxpayers who submit a return, the reduction of periodic VAT returns, and the abolition of parafiscal taxes. These changes have led to a reduction in administrative costs for both the state and taxpayers, improving the efficiency of the tax administration, especially for small and medium-sized enterprises.

However, simplification risked a temporary reduction in tax revenues, as was the case with the abolition of stamp duty. In order to compensate for these losses, the Georgakopoulos Committee proposed an increase in the VAT rate by one percentage point, a proposal that highlighted the constant tension between the need for simplification and the maintenance of fiscal stability.

International experience, as the study notes, shows that radical tax reforms can reduce public revenues in the short term, but in the long term they boost economic activity and lead to an increase in revenues through the broadening of the tax base. The cases of Ireland and the United Kingdom are prime examples: there, a reduction in tax rates, especially for small and medium-sized enterprises (from 0% to 10%), has resulted in an increase in employment, investment activity and tax compliance. Economic theory confirms that a reduction in the tax burden by one percentage point can increase employment by up to 750,000 people on a European scale.

According to the Foundation for Economic and Industrial Research (IOBE), substantial tax reform must be part of an overall fiscal consolidation plan, which takes into account the dynamics of public debt, the course of primary expenditure and the sustainability of the social security system. Greece, however, under the pressure of the Maastricht criteria, followed the opposite direction, choosing to increase taxes instead of reducing spending and consolidating state structures.

International practice suggests that successful reforms are achieved by broadening the tax base and reducing rates at the same time, while removing undue exemptions and privileges. This approach reduces distortions in the economy, reduces incentives for tax evasion and leads to a fairer distribution of the burden. In contrast, the Greek practice of constant amendments and additions to the tax framework created a complex and unstable system, which increased uncertainty and undermined citizens' confidence.

A central element of the reform is the tax administration, which is recognized as the foundation of the tax system. The improvement of the relationship of trust between the state and the citizen emerges as a necessary condition for the success of any reform. The state must show respect for the citizen, treating him not as a potential tax evader but as an equal partner in the fiscal effort. Accordingly, the citizen must be convinced that his tax burdens are properly utilized for the benefit of society as a whole.

The study proposes the creation of a stable, transparent and reliable tax framework, with the abolition of retroactive taxation, excessive exemptions and "loopholes" of legislation. At the same time, it proposes measures such as the establishment of a single tax policy for all legal forms of business, the computerization of communication through the TAXIS system, the creation of a special cadastre and the lifting of banking secrecy. It is also proposed to create a "Taxpayer Charter", which will define

the rights and obligations of citizens and administration, accompanied by service efficiency indicators (such as request response time and waiting at the Tax Offices).

In addition, the Foundation for Economic and Industrial Research (IOBE) points out that effective tax administration requires competent and continuously trained staff, strategy setting, rational use of resources and stable political will. These reforms must be supported by institutional guarantees of meritocracy, such as the selection of heads based on objective criteria and the periodic transfer of employees to avoid dependence on local interests.

Globalization and technological progress are creating new challenges for taxation. The increase in cross-border transactions, tax havens, electronic money and intra-group trade of multinationals make international cooperation and exchange of information necessary. The OECD and the European Union have already moved in this direction, focusing on tackling tax competition and regulating the taxation of e-commerce. Specifically for the EU, the study proposes harmonisation of indirect taxes (VAT and excise duties) and the abolition of all taxes that hinder cross-border business activities, without seeking to impose a single tax rate.

At the same time, it is proposed to link tax reforms to environmental and public health protection policies, as well as to ensure that any tax reduction is accompanied by a rationalization of public spending. The reform must be sustainable, support fiscal discipline and combine burden reduction with the strengthening of public services.

### **3.9 Proposals of the Athens Bar Association (2010): Justice, transparency and e-supervision**

The DSA's proposals for the income tax reform in 2010 were realistic and at the same time progressive. Central was the proposal for a single progressive and indexed tax scale for all incomes, with a maximum rate of 40%. The reasoning was based on the principle of ability to pay, i.e. the taxation of net income after deduction of necessary living expenses.

In addition, a 100% deduction of expenses based on receipts was proposed, with the aim of combating tax evasion. The loss of revenue resulting from the deduction of expenses would be compensated by an increase in declared income and VAT revenues due to greater transparency of transactions. This is a proactive approach to tax compliance, where the state does not punish tax evasion after the fact, but incentivizes the disclosure of actual transactions.

The DSA stressed the need for electronic interconnection of state agencies and businesses, through electronic invoicing and invoice distribution systems. eGovernment was considered necessary to enhance transparency and the targeted selection of files for tax audit based on objective criteria.

Particular emphasis was placed on the presumptions of subsistence, which, according to the Association, were necessary due to extensive tax evasion. While it was recognised that the presumptions pose risks of overtaxation, it was deemed necessary to reform them so that they realistically reflect the actual ability to pay tax and correlate with the receipt system.

In conclusion, the DSA's approach focused on equality and transparency, proposing a simpler, electronically interconnected system and adapted to modern economic reality.

### **3.10 The IOBE study (2018): Simplification, efficiency and tax administration**

In 2018, in collaboration with diaNEOsis, the Foundation for Economic and Industrial Research (IOBE) published an in-depth study on income taxation in Greece. This study was a continuation of the previous concerns, but with a clearly more technocratic and developmental orientation. The Foundation for Economic & Industrial Research (IOBE) pointed out that Greece maintains high tax rates, a limited tax base and low tax collectability.

The main proposal was to reduce the top and intermediate tax rates in order to boost employment and attract investment. At the same time, it is proposed to limit the brackets to one or two, in order to

reduce complexity and limit the tendency for income shifting or tax avoidance. This proposal is linked to international experience, according to which the simplification of tax rates leads to greater tax compliance and increased revenues.

The Foundation for Economic and Industrial Research (IOBE) argued that broadening the tax base through a reduction in tax deductions and exemptions would strengthen the redistributive role of taxation. However, redistribution should not be pursued through overtaxation but through targeted public spending to avoid distortions in economic activity.

An important proposal of the study was the gradual abolition of subsistence presumptions, which are considered an outdated mechanism for determining the tax base. In their place, it is proposed to use electronic cross-checking systems and plastic money, so that tax audits become more accurate and targeted.

The Foundation for Economic and Industrial Research (IOBE) went even further, proposing an institutional mechanism for evaluating tax legislation, with semi-annual activity reports, impact analysis and monitoring of the effectiveness of each bill after its implementation. This proposal reflects the need for accountability and transparency in legislation, preventing the ongoing deregulation of the tax framework.

The study also highlighted that tax administration is a critical success factor. The reorganisation of tax authorities, their staffing with competent auditors and the full digitalisation of the tax administration are considered prerequisites for reducing corruption, compliance costs and restoring citizens' trust in the state.

### **3.11 The Pissarides Commission Report (2020): Linking taxation to growth**

The Pissarides Report on the Development Plan of the Greek Economy (2020) offers a broader strategic perspective. It is not limited to technical proposals but attempts to integrate tax reform into the overall model of economic growth. According to the report, in the period 2010–2019 Greece recorded an increase in tax revenues from 32% to 38.9% of GDP, despite the shrinking production base. This development has led to overtaxation of labour, real estate and energy products, affecting competitiveness and employment.

The Commission identifies that the tax structure reflects and reproduces the chronic distortions of the Greek economy: a high share of self-employed, an extensive shadow economy, low productivity and high unemployment. To address these problems, it proposes a multi-level strategy:

1. Simplification and stability of the tax system: A stable regulatory framework, with a long-term horizon, that will prevent investor uncertainty.
2. Transfer of certain tax responsibilities to local level (municipalities) to enhance accountability and efficiency.
3. Harmonization of income tax rates with the Eurozone average, avoiding overtaxation of production rates.
4. More favorable taxation of investments in mechanical equipment and technological renewal, in order to increase productivity.
5. Limiting the smuggling of fuel and tobacco products, as well as tax evasion by strengthening incentives for electronic transactions.
6. Reduction of taxation on energy products, in order to limit distortions in the competitiveness of industry.
7. Strengthening household savings and capital accumulation through tax incentives.
8. Judicial decongestion of tax disputes and strengthening of administrative efficiency.

The Pissarides report links taxation to macroeconomic stability, productivity and the strengthening of middle incomes. It points out that the simplification and security of the tax regime are fundamental conditions for attracting investment and restarting growth.

#### **4. Comparative discussion and scientific commentary on the effectiveness of reforms**

A comparative examination of the 1990–2020 tax reports shows that, despite the divergence of approaches, there has been a common orientation towards a fairer, more efficient and simpler tax system. However, the proposals were rarely fully implemented, due to institutional weaknesses and political discontinuity.

The Commission of 1990 was the first to attempt to link fiscal policy with budgetary stability. The introduction of the concept of "tax compliance" was an important step in theory, but in practice it was not supported by the available control mechanisms. The absence of computerised administration and the dependence of services on political orientations undermined the sustainability of reforms (OECD, 1997).

In 1992, the reforms took on a European character, with the aim of harmonizing and incorporating Community directives. Despite legal progress, adjustment policies have been limited to superficial corrections, without a comprehensive reorganization of the tax administration. The implementation deficit reflected the general problem of the institutional capacity of the Greek state, which remained focused on legislation rather than implementation.

The Hellenic Society of Tax Law (1990–1997) gave the concept of tax reform a scientific dimension. Its proposals introduced rational and fair tax criteria, but their influence on state policy was limited. Tax reform, despite theoretical progress, remained "state-centric" and not multi-layered, ignoring the needs of social consensus and transparency.

The Georgakopoulos Committee (2002) marked an effort at institutional maturation. For the first time, the reform was approached holistically, with a combination of technocratic analysis, political strategy and social targeting. The introduction of the TAXISnet system was a crucial innovation that improved transparency and data collection. However, the implementation of the proposals was fragmentary, due to the lack of administrative continuity and the long-standing tendency of the state to "reinvent" tax policy with every change of government (Ministry of Finance, 2002).

The Economic Chamber of Greece (2002) differentiated itself in terms of methodology, offering an institutional framework for the evaluation of tax policy. His analysis moved at a macroeconomic level, highlighting the importance of fiscal stability for economic growth and investment. The Chamber argued that the constant changes in the legislation produce tax uncertainty and damage the confidence of citizens. Although this position has been adopted in subsequent policies, its practical implementation remains a challenge.

Overall, the 1990–2002 reports highlight the structural paradox of Greek tax policy: high theoretical adequacy, but low practical applicability. The success of the reforms was limited by fragmentation, lack of institutional continuity and political instability. The lack of evaluation of results and the absence of independent tax authorities until 2016 have contributed to the perpetuation of a system that remains complex and uneven.

The proposals of the IMF and the Hellenic Federation of Enterprises (SEV) in 2004, although they came from different starting points, show significant convergences in their orientation. Both bodies underlined the need to modernize the tax framework, simplify procedures, reduce rates and strengthen the tax administration. At the same time, they expressed the common position that taxation should act as a lever for growth, not as an obstacle to entrepreneurship.

The IMF's recommendations focused more on fiscal consolidation and the stability of the tax environment, while SEV's proposals highlighted the dimension of competitiveness and entrepreneurial freedom. However, both approaches were linked to a common goal: the formation of a modern, transparent and developmental tax system, capable of strengthening citizens' trust and harmonizing with European practices.

The scientific assessment of the reports shows that the tax reform in Greece did not fail due to a lack of knowledge, but due to administrative inertia and social mistrust. The institutional framework failed to establish a culture of stability and accountability, and repeated reforms often contradicted each other. This long-standing discontinuity is the main reason for the limited effectiveness of Greek tax policies.

Tax policy in Greece is one of the most critical fields of public policy, as it is directly linked to fiscal stability, social justice and the competitiveness of the economy. The period from 2010 to 2020 was marked by successive crises – fiscal, financial and then pandemic – that brought back to the fore the constant need for a stable, fair and efficient tax system.

The proposals of the Athens Bar Association (2010), the Foundation for Economic and Industrial Research (IOBE) (2018) and the Pissarides Committee (2020) reflect the gradual shift of Greek tax thinking from the correction of individual distortions to an overall reform strategy aimed at sustainable development.

The three actors present different perspectives but converge on critical points:

- Justice and tax equality: The DSA highlights the need to redistribute the burden based on the ability to pay. The Foundation for Economic and Industrial Research (IOBE) and the Pissarides Committee are shifting the debate towards economic efficiency, but without ignoring the importance of social justice.
- Simplification and stability: All stakeholders point out that the multiplicity of laws and the instability of the tax system are key inhibiting factors.
- Technological modernization: From the electronic invoicing of the Athens Bar Association to the "digital tax administration" of the Foundation for Economic and Industrial Research (IOBE) and the administrative reform of the Pissarides Committee, technology is considered the lever of transparency and efficiency.
- Growth and investment: The Pissarides Commission goes beyond fiscal limits, linking taxation to the improvement of the investment environment and productive reconstruction.

Greece's tax structure over time has been characterized by a high degree of complexity, inefficiency and inequality. Since the early 2010s, the country has faced high budget deficits, low tax compliance, and an extensive shadow economy. The Athens Bar Association (DSA) in collaboration with the Ministry of Finance in 2010 highlighted one of the main problems: the unequal distribution of the tax burden. According to his findings, the main tax burden fell disproportionately on employees and pensioners, i.e. on social strata that could not hide income.

The lack of effective implementation of the rules and the existence of numerous exemptions led to the systematic tax avoidance of high-income professional groups, which, while showing elements of luxury living, declared extremely low incomes. This distortion affected tax justice and reinforced the phenomenon of social discontent with the state.

## 5. Conclusions

The comparative analysis of the tax reports of the period 1990–2020 demonstrates that the evolution of Greek tax policy has been the result of a continuous but incomplete reform process. This period marked the country's effort to harmonize with the European standards of financial management, but at the same time highlighted the internal weaknesses of the Greek administrative system.

The tax reports of this decade are distinguished by their rational documentation and emphasis on transparency, stability and fairness. Despite theoretical convergences, the practical implementation of the proposals has been limited. The multiplicity of laws, the instability of the rules and the political interventionism in the administration prevented the creation of a stable tax policy framework.

The 1990 Commission introduced concepts such as equality before the law and compliance, laying the foundations for a more objective system. In the light of European integration, the 1992 proposals focused on technical adjustment, but without any substantial restructuring. The Hellenic Society of Tax Law highlighted the legal dimension of tax injustices, while the Georgakopoulos Commission (2002) gave a holistic character to the reform, introducing the principles of digital governance and transparency. The Economic Chamber of Greece has completed the cycle by linking fiscal stability with macroeconomic growth.

A comparative view of the reports shows that the effectiveness of reforms depends on three interrelated factors:

1. Institutional continuity and administrative adequacy: without permanent structures, reforms remain fragmented.
2. Political will and social consensus: changes in taxation require social acceptance and political stability.
3. Technological and organizational adaptation: digitalization and computerization of the administration are key prerequisites for transparency and the reduction of tax evasion.

The analysis shows that the Greek tax system has long been the product of political pragmatism and not of institutional strategy. Reforms focused on short-term fiscal adjustment, neglecting long-term institutional stability. This has resulted in a long-term loss of trust between the state and citizens – a crucial element for the functioning of any democratic tax policy.

The evaluation of the reports reveals that tax reform is not just an economic necessity, but also a cultural process, requiring continuous education, transparency and meritocracy. The strengthening of tax awareness, the stability of the legal framework and the independence of the tax authorities are prerequisites for a modern, efficient and socially just tax system.

The historical experience of the years 1990–2002 offers valuable lessons: any reform that ignores institutional continuity, administrative capacity and social trust is doomed to fail. The proposals of these committees remain relevant, constituting the basis for modern tax policy that must combine efficiency, transparency and social balance.

In 2004, the Foundation for Economic and Industrial Research (IOBE) concluded that successful tax reform requires a medium-to-long-term tax policy program, which will set clear targets, identify the necessary instruments and prioritize. The trajectory of tax revenues must be closely linked to the evolution of public expenditure, as since the transfer of monetary policy to the European Central Bank, the fiscal sector has become the main economic policy tool.

The structural weaknesses of the Greek tax system – overregulation, instability, legal uncertainty, lack of predictability and inability to combat tax evasion – require deep institutional transformation rather than piecemeal amendments. The reform must have the character of a "tax revolution", with an

emphasis on simplicity, transparency and fairness, in order to strengthen the social legitimacy of the tax system and restore the trust of citizens and businesses in the state.

In conclusion, 2004 marked a significant turning point in the debate on tax reform in Greece. The proposals of the IMF, the Hellenic Federation of Enterprises (SEV) and the Foundation for Economic and Industrial Research (IOBE) were not just technical recommendations, but constituted an overall view of the role of taxation in economic growth, the enhancement of productivity and the improvement of the relationship between the state and the citizen. Their analysis continues to have theoretical and practical value, as it highlights the constant need for a stable, fair and competitive tax system, a cornerstone of any modern and sustainable economy.

The evolution of the tax proposals from 2010 to 2020 reflects the transition of Greek tax policy from a reaction to crises towards a growth strategy. Fairness, simplicity and efficiency are the three pillars of a modern tax system. However, in order to achieve real reform, consistency, administrative capacity and political will are needed to put tax policy at the service of sustainable development and social cohesion.

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# Corporate governance and boardroom diversity through agency theory: a literature review

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## Abstract

While the positive impact of gender-diverse boards on corporate decision-making, innovation, and performance is well-documented, further investigation is necessary to understand how female leadership specifically influences agency costs, information asymmetry, and governance effectiveness. Grounded in agency theory, this review examines the role of female directors in strengthening corporate governance structures by reducing information asymmetry and agency costs. The analysis identifies four key findings: female directors enhance internal monitoring and oversight, leading to reduced agency costs; they promote greater transparency and higher-quality financial reporting, limiting earnings management; their presence is positively correlated with increased firm value, particularly in family-owned enterprises; and they contribute to stronger Environmental, Social, and Governance (ESG) practices, advancing corporate social responsibility. Overall, this study demonstrates that female directors improve governance outcomes through both effective oversight and a heightened commitment to ethical standards, significantly shaping corporate policy and strategic decision-making.

**Keywords:** *Corporate Governance, Board of Directors, Gender Diversity, Agency Theory, Firm Performance, Corporate Social Responsibility (CSR)*

## 1. Introduction

The importance of gender diversity in corporate governance has gained significant attention, with research showing that diverse boards enhance decision-making, risk assessment, and innovation

(Carter, Simkins, & Simpson, 2003; Huang, Wan Ahmad, & Saad, 2025). Companies with greater female representation often report improved financial performance, stronger company culture, and higher stakeholder engagement. Despite these findings, there remains a critical gap in the theoretical understanding—particularly through the lens of agency theory—of how female leadership affects agency costs, information asymmetry, and corporate accountability. This review addresses this gap by analyzing how women directors strengthen governance structures and organizational outcomes.

This literature review aims to systematically examine how the presence of female directors on corporate boards influences agency costs, financial reporting quality, and corporate governance practices, through the theoretical lens of agency theory (Fama & Jensen, 1983; Ha, Hung, & Xuan, 2023; Jensen & Meckling, 2019). Specifically, it explores how traits traditionally associated with female leadership, such as ethical decision-making and diligent monitoring, contribute to reducing information asymmetry between shareholders (principals) and managers (agents), thereby enhancing organizational performance and accountability.

This study is grounded in **agency theory**, as articulated by Jensen and Meckling (1976) and expanded by subsequent scholars (Eisenhardt, 1989; Fama & Jensen, 1983). Agency theory examines the inherent conflicts of interest arising from the separation of ownership and control in corporations, particularly due to information asymmetry between principals (shareholders) and agents (managers). Within this framework, the literature reviewed highlights how gender diversity in boardrooms—specifically the inclusion of female directors—can strengthen internal monitoring, reduce earnings management, and align managerial actions more closely with shareholder interests. Female directors, through their ethical orientation and heightened oversight behaviors, are positioned as crucial governance mechanisms for mitigating agency costs and fostering more transparent, accountable corporate environments.

The findings of this review reveal that female directors play a critical role in enhancing corporate governance by serving as superior internal monitors, thereby reducing agency costs and improving transparency. Their presence significantly mitigates earnings management, strengthens internal control systems, and narrows the information gap between management and shareholders (Alhossini, Zalata, Samaha, & Hessian, 2024; Alluwia & Sarun, 2018; Gunawan, Sofian, Wijaya, & Dwijayanti, 2021; Imura, 2024). Moreover, female leadership is associated with improved financial reporting quality, particularly in firms audited by non-Big-4 auditors, and is positively correlated with enhanced firm value, especially in family-owned businesses (Buachoom, Amornkitvikai, Al Farooque, & Sun, 2023). Beyond financial outcomes, female directors also contribute to the development of stronger Environmental, Social, and Governance (ESG) practices, reinforcing ethical standards and corporate responsibility (Huang et al., 2025). Collectively, these results underscore the tangible impact of gender diversity on governance effectiveness and organizational sustainability, offering robust support for the application of agency theory in explaining the value of female participation in corporate leadership.

This study builds upon existing research by systematically reviewing the role of gender diversity within the framework of corporate governance, with a particular focus on interpretations rooted in agency theory. It highlights how the presence of female directors on corporate boards influences key financial performance indicators, firm value (Alhossini et al., 2024; Amin et al., 2022; Buachou et al., 2023), and environmental and social factors (Huang et al., 2025). A central contribution of this research is the organization and synthesis of theoretical frameworks that demonstrate the significant impact of female leadership on reducing agency costs. Through promoting more effective governance, enhancing decision-making processes, and fostering a culture of accountability, female directors play a critical role in aligning managerial actions with shareholder interests and improving overall corporate performance. Moreover, the study emphasizes that agency costs are not only reduced by structural governance mechanisms but are also profoundly influenced by personal traits

often associated with female leaders—particularly their tendency for meticulous monitoring and greater attention to internal controls (Alhossini et al., 2024). This heightened diligence strengthens transparency and trust within organizations and shapes the strategic orientation of corporate policies. Together, these insights underscore the essential role of boardroom diversity in enhancing governance effectiveness, reinforcing the relevance of agency theory in contemporary corporate structures.

The structure of this article is organized as follows. Section 2 reviews the theoretical background, focusing on agency theory and its relevance to corporate governance and boardroom diversity. Section 3 describes the methodology adopted for the systematic review of the selected studies. Section 4 presents the key findings, beginning with an analysis of the relationship between female board representation and firm performance (Section 4.1), followed by an examination of the influence of female directors on corporate social responsibility (CSR) initiatives, financial reporting quality, and governance practices (Section 4.2). Section 5 discusses the broader implications of female participation in corporate leadership within the framework of corporate governance. Finally, Section 6 concludes the article by summarizing the main findings, highlighting their theoretical and practical contributions, and offering directions for future research.

## **2. The Agency Theory within the framework of corporate governance and boardroom diversity**

This subsection explains the way that prior literature uses agency to interpret how female presence in the boardroom (boardroom diversity) affects corporate governance. To better understand this concept, we will break down the different terms used in the conceptualization of agency theory into the framework of corporate governance and female presence in the boardroom (Jensen & Meckling, 1976, 2019).

Agency theory, as introduced by Jensen and Meckling (1976), addresses the fundamental issue of the separation between ownership and control in modern corporations. This separation arises when the owners of a firm (the principals) delegate decision-making authority to managers (the agents), who are responsible for operating the firm on their behalf. Jensen and Meckling (1976) argued that this principal-agent relationship is inherently prone to conflicts of interest, as agents may pursue personal objectives that do not align with those of the principals. These divergent interests are exacerbated by information asymmetry, wherein agents possess more detailed knowledge about the firm's operations than the principals. This imbalance can lead to agency costs, which include monitoring expenses, bonding costs, and residual losses, all incurred in an effort to align managerial actions with shareholder interests (Eisenhardt, 1989; Fama & Jensen, 1983; Shleifer & Vishny, 1997).

At first glance, it may seem that both principals (shareholders) and agents (managers) share a common objective: the maximization of firm profitability. Managers often receive compensation tied to firm performance—such as profit-based bonuses or equity incentives—while shareholders benefit directly through dividend payments and increases in share value, both of which are linked to the firm's financial success. Given this apparent alignment, one might question why conflicts of interest arise between these two parties (Jensen & Meckling, 1976).

The core of this conflict lies in information asymmetry. Managers, as internal actors, have greater access to real-time and in-depth knowledge about the firm's operational and financial health. Shareholders, by contrast, are external to the firm's day-to-day management and must rely on financial disclosures and periodic reports (Eisenhardt, 1989; Jensen & Meckling, 1976). This information imbalance allows managers the opportunity to engage in earnings management, manipulating financial statements to present a more favorable short-term picture of performance, which may benefit them personally through increased compensation or reputation, while potentially harming the long-term interests of shareholders (Fama & Jensen, 1983).

This divergence of interests, fueled by unequal access to information, represents a central concern in agency theory (Eisenhardt, 1989; Shleifer & Vishny, 1997). Consequently, much of the literature focuses on identifying mechanisms that can reduce information asymmetry and enhance monitoring. One such mechanism is the inclusion of women in corporate boardrooms. Evidence suggests that gender-diverse boards are more effective in scrutinizing managerial actions, asking critical questions, and demanding greater transparency, thereby narrowing the information gap between managers and shareholders (Alhossini et al., 2024).

Based on the previous assumption, we can understand the role of female representation within the framework of agency theory and its impact on corporate governance (Carter et al., 2003). Specifically, research indicates that women tend to be more ethical and risk-averse. Consequently, a significant portion of the literature supports the idea that women help reduce information asymmetry. This reduction in asymmetry means that moral hazard is diminished, aligning the interests of the agent and the principal. Therefore, the presence of women in corporate governance reinforces agency theory.

### 3. Methodology

This comprehensive review study employs a systematic approach to collect and analyze scholarly articles that focus on the intersection of corporate governance and the representation of women in boardrooms. Drawing inspiration from the analytical framework established by Chatzis, Thanasas, & Koulidou (2023), we conducted our research using carefully selected keywords within the Google Scholar database. Specifically, we initiated our search by targeting articles where the keywords “corporate governance” and “female” are present in the title (Chatzis, Thanasas, & Koulidou, 2023). This method allowed us to narrow our focus on relevant literature that addresses critical issues surrounding gender diversity and leadership roles in corporate settings. The initial number after this research was 59 studies. To refine our research focus, we emphasized the representation of women in the boardroom as it relates to agency theory. As previously noted, our review specifically aims to explore this dynamic. To achieve a more targeted analysis, we limited our selection to articles that explicitly incorporated agency theory within their theoretical frameworks. This focused approach allowed us to narrow the pool of relevant literature down to 24 key studies that align with our research objectives. Each selected study contributes valuable insights into how female representation in executive roles influences organizational behavior and decision-making processes, thereby underscoring the practical implications of agency theory in corporate governance. Due to limited access to certain publications, our review was confined to 13 studies, which met our inclusion criteria and were available through accessible academic databases. Table 1 discloses our selection process.

**Table 1:** *Final Article collection procedure*

| Article collection procedure                                                          | # of studies |
|---------------------------------------------------------------------------------------|--------------|
| Initial sample of studies resulted from “corporate governance” and “female” key words | 59           |
| Less: Articles that do not included the agency theory in their theoretical framework  | (35)         |
| Less: Access-Limited studies                                                          | (11)         |
| Final number of studies                                                               | 13           |

### 4. Presentation of the studies

A landmark study conducted by Carter et al. (2003) revealed that increasing female representation in the boardroom led to a significant reduction in agency costs among Fortune 100 firms. Agency costs arise from principles of agency theory, which posits that there is an inherent disparity in information between two parties: the agents (management) and the principals (shareholders). Agents possess more comprehensive knowledge than the principals, leading to a phenomenon known as information

asymmetry (Jensen & Meckling, 1976). As previously mentioned, agents (management) often possess more information than principals (shareholders) because the latter are not involved in the firms' day-to-day operations. This situation creates what is known as information asymmetry (Eisenhardt, 1989). To reduce this information asymmetry, agency costs arise. These costs include expenses related to monitoring the agents, as well as costs associated with aligning management's interests, known as bonding costs, with those of the shareholders through performance incentives. Additionally, there may be residual losses that occur due to conflicts of interest between agents (management) and principals (shareholders) (Eisenhardt, 1989; Jensen & Meckling, 1976).

#### **4.1 Female presence in the boardroom and firm-performance**

Numerous academic articles examine the impact of female representation within corporate leadership on overall firm performance, often elucidating these effects through the lens of agency theory. Research suggests that having more women in leadership roles can enhance decision-making processes (Adams & Ferreira, 2009; Carter et al., 2003).

Alluwia, F., & Sarun, A. (2018) focused on the monitoring cost in the agency theoretical framework. Specifically, they observed that the presence of women in the boardroom might enhance managerial monitoring. From this perspective, it is evident that gender diversity strengthens the Board of Directors by enhancing their effectiveness in monitoring management, thereby reducing the monitoring costs incurred by shareholders (Alluwia & Sarun, 2018). In this context, it is important to elaborate that monitoring costs arise from shareholders, particularly within the framework of agency theory, which focuses on the principal-agent relationship. In this case, the principals are the shareholders, while the agents are the management.

Alluwia, F., & Sarun, A. (2018) found that a higher participation of female directors on the Board of Directors leads to a decrease in agency costs. This reduction is attributed to women's ability to withstand monitoring from the principals. Women are often more willing to ask questions and raise concerns about various issues that their male counterparts might overlook or undervalue. This brings a different dynamic to discussions, as female directors tend to be more engaged and thorough, ultimately enhancing the quality of decision-making. As a result, monitoring costs are reduced, and shareholders develop greater trust in the boardroom. Consequently, this characteristic contributes to more effective corporate governance and benefits the entire firm.

A study conducted across nine sub-Saharan African countries (2007–2019) examined how women's presence in corporate governance affects organizational practices, particularly earnings management (Mensah & Boachie, 2023). The results showed that greater female representation on boards significantly reduces earnings manipulation. This effect is attributed to the ethical standards and transparency that women tend to promote, fostering stronger accountability within organizations. The study concludes that women in leadership roles help mitigate boards' endorsement of aggressive earnings management policies. These findings support agency theory, which suggests that diverse governance structures improve oversight and better align stakeholder interests, ultimately enhancing corporate integrity and reducing agency-related risks (Mensah & Boachie, 2023).

To further substantiate this perspective, Buachou et al. (2023) demonstrated that the presence of women on corporate boards significantly enhances firm value, with a particularly notable effect observed in family-owned businesses. This evidence challenges the traditional assumption that family-owned firms are prone to lower overall valuation (Buachoom et al., 2023). Consistent with agency theory, their findings highlight that gender diversity, alongside ownership structure, plays a critical role in protecting shareholder interests by strengthening monitoring functions and improving governance effectiveness. Family-owned businesses often drag down firm value (Buachoom et al., 2023). On another study that Amin et. al. 2022, which was based on the Pakistan Stock Exchange (PSX), and presented represents the nonfinancial sector from 2008 to 2019. This research indicates that the presence of women in the boardroom is positively correlated with improved financial

performance (Amin, Ali, Naseem, & Ahmad, 2022). This significant finding highlights the importance of having female directors and suggests that their inclusion could be made mandatory. This diversity contributes to overall firm performance, enhancing productivity and profitability (Buachoom et al., 2023).

Another important dimension through which female directors contribute to shareholder protection is their enhanced monitoring capability (Alhossini et al., 2024). Using a sample of U.S. firms, Alhossini et al. (2024) found that female directors demonstrate a greater sense of responsibility in overseeing managerial actions, thereby safeguarding shareholder interests. Notably, their monitoring effectiveness persists across firms with both strong and weak corporate governance structures, highlighting the critical role of female directors in reinforcing internal oversight mechanisms. Additionally, it was found that the presence of females reduces earnings management in firms, especially in non-Big-4 firms (Alhossini et al., 2024).

#### **4.2 Corporate social responsibility, financial reporting and female presence in the boardroom**

Numerous studies have demonstrated the significant impact of Environmental, Social, and Governance (ESG) factors on corporate performance and ethical decision-making (Huang et al., 2025). A notable aspect of this research highlights the perception that women are often viewed as more ethical leaders compared to their male counterparts. For instance, Huang (2025) supports this notion by showing that female CEOs tend to influence the decision-making processes within their organizations in ways that actively promote innovation, sustainability initiatives, and philanthropic activities.

Moreover, empirical evidence suggests that women leaders contribute to improved financial reporting practices due to their innate skills as vigilant monitors. According to agency theory, independent outside directors—particularly those who are women—are expected to function as effective overseers of corporate governance. Their presence on the board strengthens internal control systems by minimizing information asymmetry between management and shareholders (Pucheta-Martínez, Bel-Oms, & Olcina-Sempere, 2016). This, in turn, enhances the quality of financial reporting and increases transparency, ultimately fostering greater trust among investors and stakeholders alike. By prioritizing ethical governance and financial integrity, female leaders not only advance their organizations but also set a benchmark for best practices in corporate responsibility (Pucheta-Martínez et al., 2016). Research indicates that female directors tend to exercise better oversight and enhance the quality of audit processes within organizations. Their diverse perspectives can contribute to more thorough scrutiny of financial reporting and governance practices, leading to improved accountability and transparency in corporate environments (Ha et al., 2023).

### **5. Corporate governance and female presence**

This study provides insight regarding the way that female directors operate within the framework of corporate governance. However, our literature review aims at pointing out the way that the female presence is interpreted through the agency theory (Imura, 2024; Lin, 2021). Specifically, we try to explain how the traits of female directors affect the agency cost and information asymmetry in a way that affects the relation between the interests of shareholders (principals) and management (agents).

A significant finding in our study is that female directors serve as superior internal monitors within organizations (Alluwia & Sarun, 2018). This observation highlights their ability to effectively oversee and regulate internal processes, ensuring enhanced compliance with company policies and promoting a culture of accountability. This, in turn, safeguards shareholder interests by ensuring that managerial actions remain within ethical standards. This mechanism contributes to a decline in earnings management—where managers intentionally adjust financial statements to present the firm in a more favorable light. By limiting such practices, the integrity and completeness of financial disclosures are

strengthened, thereby narrowing the gap in information between management and shareholders. Greater transparency in reporting enables stakeholders to make better-informed decisions based on accurate and reliable data.

Furthermore, the reduction in information asymmetry contributes to lower agency costs, which arise from efforts to mitigate conflicts between managers (agents) and owners (principals). Notably, even in settings with weak regulatory enforcement or limited board oversight, this dynamic promotes greater alignment between managerial behavior and shareholder interests. As a result, corporate governance frameworks are strengthened, fostering higher transparency, improved accountability, and enhanced operational efficiency.

The conclusion presented in this discussion emphasizes that gender diversity is far more than a mere symbolic gesture. It asserts that women in leadership roles are not mere tokens; rather, they are vital contributors who bring invaluable perspectives and skills to the upper echelons of organizations (Guldiken, Mallon, Fainshmidt, Judge, & Clark, 2019; Rixom, Jackson, & Rixom, 2023). There are tangible and they impact governance structure particularly in filling gaps in monitoring and reducing managerial opportunism. This literature review highlights four main points, each of which is elaborated upon in the subsections below. These points reflect the key findings offer a comprehensive understanding of the association of corporate governance and female directors through the agency theory.

First, female directors contribute to the reduction of agency costs. As noted in prior literature, the presence of female directors minimizes agency costs primarily through their strong influence on managerial monitoring (Alhossini et al., 2024; Alluwia & Sarun, 2018). Female directors are more likely to engage in thorough oversight behaviors, such as posing critical questions that their male counterparts might overlook, challenging management decisions, and ensuring that financial reporting remains transparent and accountable. These actions serve to protect the interests of principals (shareholders) by strengthening internal governance.

Second, this research indicates that the presence of women in leadership roles enhances transparency and financial reporting within organizations. This improvement plays a critical role in curbing earnings management and opportunistic behavior (Gunawan et al., 2021), particularly in firms that are audited by non-Big-4 auditors. The positive impact of female leadership serves as a compensatory governance strength, contributing to more ethical financial practices (Alhossini et al., 2024).

Empirical research demonstrates that the presence of women in corporate leadership roles is positively correlated with increased firm value (Bello, Hashidu, Abubakar, & Lass, 2019; Gudjonsson, 2015). This relationship is particularly pronounced in family-owned businesses, which have often been observed to underperform. Notably, the inclusion of women in these firms not only ensures compliance with diversity standards but also leads to significant strategic advantages. Enhanced female representation drives improved productivity, fosters greater innovation, and ultimately contributes to higher profitability. This trend underscores the importance of diverse perspectives in shaping firm strategies and achieving sustainable growth, particularly in the context of family-owned enterprises.

Ultimately, women tend to prioritize ethical behavior, leading to the development of stronger Environmental, Social, and Governance (ESG) indicators. This focus contributes significantly to the evolution of corporate social responsibility (CSR) policies (Huang, 2025). Female leaders often adopt a collaborative and inclusive leadership style that fosters trust among stakeholders, which is essential for building long-term relationships. By embedding these values into corporate strategies, women in leadership positions can drive meaningful change in their organizations and the broader community.

## 6. Conclusions

This study highlights that female directors strengthen internal monitoring, reduce agency costs, and improve financial reporting quality by limiting earnings management. Their presence enhances firm value, particularly in family-owned businesses, and promotes stronger ESG practices. Overall, gender diversity plays a critical, tangible role in improving corporate governance, transparency, and long-term organizational sustainability.

This research builds upon existing literature by systematically reviewing studies that investigate the impact of gender diversity within the framework of corporate governance. It specifically focuses on the interpretation and analysis of articles that apply agency theory to examine the various effects of female directors' presence on corporate boards, particularly regarding financial performance and environmental indicators. This stems from two significant contributions. Initially, we systematically organized the theoretical frameworks that contribute to the existing literature, emphasizing the significant impact of women's presence in the boardroom on agency costs within organizations. We present a series of empirical studies that investigate various firm indicators, such as financial performance metrics, overall firm value (Alhossini et al., 2024; Amin et al., 2022; Buachoom et al., 2023), and specific environmental and social factors (Huang et al., 2025). Each of these studies highlights how the inclusion of women in leadership positions influences agency costs by promoting more effective governance, enhancing decision-making processes, and fostering a culture of accountability. This body of research collectively underscores the essential role that diverse boards play in mitigating agency costs and improving overall corporate performance. Therefore, a major contribution of this study is the demonstration that female directors have a meaningful impact on reducing agency costs, which in turn significantly influences the formulation and implementation of various corporate policies. On the other hand, a significant contribution of this study is the finding that agency costs are profoundly influenced by a characteristic often associated with women: their propensity for thorough monitoring. Research indicates that shareholders tend to place greater trust in female leaders due to their innate curiosity and meticulousness in investigation and internal control processes (Alhossini et al., 2024). This heightened attention to detail and commitment to oversight foster a sense of accountability and transparency within organizations. Consequently, this trait significantly shapes the decision-making processes within boardrooms, ultimately guiding the formulation of corporate policies and strategies.

This study presents several significant implications. First and foremost, by emphasizing the critical role of diligent oversight, women can be instrumental in mitigating agency costs and improving overall organizational performance. Their diverse perspectives and collaborative leadership styles may contribute to more effective decision-making processes, fostering a culture of transparency and accountability within organizations. Moreover, these findings could serve as a valuable resource for policymakers and regulators aiming to enhance the representation of women in the boardroom. By illustrating the positive impacts of female leadership, this research advocates for initiatives that promote gender diversity at the highest levels of corporate governance. Additionally, shareholders may interpret these insights as a compelling argument for prioritizing transparency and trust within their companies. A board that incorporates women's insights is likely to be more vigilant in addressing potential risks, ultimately leading to greater investor confidence and improved financial performance. Thus, enhancing women's positions in leadership roles not only aligns with principles of equity and fairness but can also yield tangible benefits for organizational integrity and shareholder value.

While this study offers valuable insights, it also presents some notable limitations that warrant further investigation. One significant limitation is the necessity for a broader research scope, specifically focusing on a wider array of keywords related to corporate governance and gender diversity. Expanding the research parameters could enhance our understanding of the various dimensions of corporate governance and gender diversity, particularly beyond the traditional agency theory

framework. By incorporating diverse perspectives and exploring additional theoretical constructs, future research could provide a more comprehensive analysis of how these factors influence organizational performance and decision-making processes. Furthermore, the current limited accessibility to certain key articles and resources presents a significant barrier that hinders the thoroughness of this research process. By expanding access to these critical materials, we could enhance the scope and depth of our analysis, ultimately leading to more robust and credible findings. Increased accessibility would enrich the overall quality of the conclusions drawn in the article.

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# **The effect of working capital and the cash conversion cycle at the profits of French PLCs, during the period 2020-2024**

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## **Abstract**

Working capital has been the subject of study for many economists for decades. Many scientific articles have been written in order to highlight the importance of the role of working capital in the survival of businesses as it is one of the key pillars in maintaining financial balance. Working capital management, essentially means managing companies' stocks, cash, accounts payable and accounts receivable. Working capital management has become increasingly vital in the wake of global disruptions, most notably the COVID-19 pandemic. This study explores the relationship between working capital components, particularly the Cash Conversion Cycle (CCC) and the profitability of French Public Limited Companies (PLCs) during the period 2020–2024. Data were obtained from 80 French PLCs and analyzed through regression modeling and descriptive statistics. The results show a strong negative correlation between CCC and both Sales and Operating Income. Specifically, firms that successfully reduced their CCC experienced increased profitability and financial stability. This highlights the strategic importance of liquidity management and operational efficiency in enhancing corporate resilience and recovery. The findings of this research reinforce the value of proactive working capital strategies and provide key insights for decision-makers, especially during periods of economic volatility.

**Keywords:** *Working Capital, Cash conversion cycle, Liquidity, Profitability.*

## **1. Introduction**

The financial disruptions caused by the COVID-19 pandemic between 2020 and 2021 had a profound impact on global businesses, especially on liquidity management and operational efficiency. During this period, companies around the world—including French PLCs—faced unprecedented challenges such as supply chain disruptions, cash flow constraints, as well as volatility in demand. These

challenges heightened the importance of working capital management as a critical financial strategy for survival and resilience.

Working capital represents the operational liquidity available to a business and is vital for maintaining daily operations. Proper working capital management ensures that companies have enough resources to cover short – term obligations while investing in growth opportunities. In this context, the Cash Conversion Cycle (CCC) - the time it takes for a company to convert resource inputs into cash flows - has emerged as a key metric for evaluating the efficiency of working capital practices.

This study revisits and extends prior research by analyzing the relationship between working capital components and profitability in French PLCs over the period 2020–2024. The study focuses particularly on how businesses adapted their CCC during and after the COVID-19 crisis. By applying updated financial data and regression analysis, this research aims to offer fresh insights into the strategic role of liquidity in corporate recovery and performance.

### **1.1 Conceptual content**

Working capital is considered for businesses, as the blood in the human body (Peel & Wilson, 1996) (Sagner, 2010). Cash is used to purchase fixed assets, to purchase raw materials and to pay creditors. The raw materials are processed, wages and overheads are paid, which then produce goods for sale. The sale of goods can be done either in cash or by credit. In the first case, the cash is collected directly, while in the second, cash is collected by the debtors. The funds are also produced by the operation and sale of fixed assets. Part of the profit is used to pay interest, taxes and dividends, while the rest remains with the business. This cycle continues throughout the life of the business (Peel & Wilson, 1996) (Sagner, 2010).

The quantitative concept of working capital is known as gross working capital, while the qualitative concept is known as net working capital. The important classifications are a) the conceptual classification and b) the classification based on the financial reports. Moreover, in the international bibliography, according to Afza & Nazir, (2008), classification based on variability is found, a type of classification is very important for the compensation of decisions.

### **1.2 Factors determining working capital**

The optimal level of current assets according to Palombini & Nakamura (2012) and Sagner (2010), depends on the nature of the business as especially commercial and industrial companies, require more working capital resources. In contrast, public utility companies need smaller working capital. The reasons supporting the need for working capital according to Palombini & Nakamura (2012), Sagner (2010), Mansoori & Muhammad (2012) and Gill (2011), are various including and not limiting to the terms of supply, the production policy business, the seasonal sales, the availability of credits, the business credit policy, the need for growth and expansion, the sales volume, the liquidity and profitability and the external environment.

### **1.3 The Role of Working Capital Management**

According to Ukaegbu (2014), Yeshmin, & Hossan (2011), the effectiveness of proper management of working capital, can contribute to the profitable utilization of fixed assets in order to ensure long – term business success and achieve the goal of maximizing the shareholders' funds. Furthermore, a business should maintain sufficient working capital for its smooth operation. Both excessive working capital and insufficient working capital, will reduce profitability and create fertile ground for malfunctions in its operating processes. Finally, according to Belt (1979) and Nazir & Afza (2009), the risks that a company faces when it maintains high levels of working capital may be over investment in fixed assets, reckless stock market, sporadic trends, liberal credit, while the risks posed by low levels of working capital are the difficulty in implementing business plans, the payment of dividends due to lack of funds, the reduction of bargaining power in credit markets, the loss of

business reputation due to inability to cover even the everyday operating deficiencies that may arise when the company is unable to deliver on its financial promises, stagnation in growth, the possibility of borrowing funds for short-term liabilities at excessively high interest rates and finally the possibility of the company being forced to sell products to very low prices in order to obtain capital which is in urgent need.

## **2. Management of Working Capital**

According to Rafuse (1996), in order to effectively manage a company's working capital, a company must focus on four different short term assets: a) accounts receivable, b) inventories, c) cash, and d) short-term debt.

### **2.1 Accounts Receivable**

A company can manage the accounts receivable according to the credit terms. A company can also rely on factoring, with a view to shorten its cash flow. Factoring means that the company sells its receivables to a third party, which usually holds a commission of the amount payable as fees and interest (Mian, & Smith Jr, 1992).

### **2.2 Stocks**

Inventories are an additional component of current assets. Depending on the industry in which the company operates, stocks can be different types of items such as raw materials, semi – final products or final products. An idea often used to manage stocks is, the just-in-time approach (JIT). Just-in-time means that stocks are kept as low as possible in order to optimize supply chain processes and never run out (Michalski, 2009).

### **2.3 Management of cash and short-term securities**

It is a common policy for companies to maintain high levels of cash availability for liquidity purposes or to avoid unexpected large-scale capital withdrawals in the short term. The problem that usually arises from maintaining a large percentage of cash, is the cost of capital that this entails. Many companies use sweeping as a method of profit in their cash balances. Cash redemption means that the company's cash balances are transferred to one – day deposit accounts in the money market, which pay a one – day interest rate. Other short – term securities that companies can invest in cash, are commercial documents, bonds, mutual funds, corporate banknotes and mortgages (Chen, et al, 2010).

### **2.4 Operating Cycle**

According to Chakraborty (1973) and Hill et al (2010), the time required to complete the conversion of cash into a) raw materials, b) from raw materials into products in progress, c) from products in progress into finished products, d) from final products into debts and accounts receivable through sales and e) from debts and accounts receivable into cash, is called the operating cycle.

### **2.5 Movement Capital Management Techniques**

The management of working capital can depend on many different factors. It has been found that inventory management models became more common in the mid-1980s, most likely as a result of the rise of just-in-time management (Bontis, 2001).

### **2.6 Working Capital Management Difference - Fixed Assets**

Working capital management is similar to managing fixed assets in the sense that in both cases a business analyzes its impact on profitability and risk. However, the management of fixed assets and the management of working capital differ in three important respects. Firstly, time management of fixed assets is very important. Secondly, large investments in working capital, especially cash, strengthen a company's liquidity position and thirdly, the level of fixed and current assets, depends

on expected sales, but only current assets which can be adjusted to sales fluctuations in the short term (Sagner, 2010).

## 2.7 Working Capital Management Policies

A financing policy shows the ratio of current liabilities to current assets with a high index indicating aggression. A financing policy is a decision on which current assets will be used by long – term sources of funding and how much investment will be made from short – term resources. Oloo & Mwangi (2014), measured the aggressive financing policy based on total current liabilities of all the assets of a company and concluded that AFP has a positive effect on the profitability of Kenya's companies that are policy adjustments.

Kaviani et al (2014), Sahail et al (2016), concluded that working capital management is similar to managing fixed assets in the sense that in both cases a business, analyzes its impact on profitability and risk. However, the management of fixed assets and the management of working capital differ in three important respects:

- 1 Time management of fixed assets which is very important.
- 2 Large investments in working capital, especially cash, that strengthen a company's liquidity position.
- 3 The level of fixed and current assets that depends on expected sales but only current assets that can be adjusted to sales fluctuations in the short term (Sagner, 2010).

## 2.8 Calculation of Working Capital

According to Stone et al, (2013), the main ways of measuring working capital and its effective management, are sales turnover rate (DSO), accounts payable turnover rate (DPO), inventory turnover rate (DIO) and Cash Conversion Cycle (CCC). Outstanding sales, express the number of days of sales value (or revenue) still pending in balances (receivables).

Traffic sales speed / sales turnover rate (DSO) can be improved by optimizing the process of collecting receivables (accounts receivable) in a business. Also, the credit policy pursued by a company, plays a vital role since, which also affects the payment schedule of future sales (Stone et al, 2013). The ration can be seen below:

$$DSO = \frac{\text{Average accounts receivable}}{\text{Sales}} * 365$$

Due days (accounts payable) express the number of payment value days still pending at the end of the period. This number shows how many days, does the company use on average to pay its obligations. By extending this period, the company can to some extent, improve its net operating capital. (Stone et al, 2013). The ration of accounts payable turnover, can be seen below:

$$DPO = \frac{\text{Average accounts payable}}{\text{Cost of sales}} * 365$$

Outstanding inventories are an economic and business term that calculates inventory value. The value is estimated from the days of clearing the stock, based on the cost of goods sold. The result can be seen as the time required to convert the stock into revenue (Stone et al, 2013). The inventory ration can be seen below:

$$DIO = \frac{\text{Average stock}}{\text{Cost pf sales}} * 365$$

The cash conversion cycle (CCC) is a combination of the previous measurements. Cash conversion cycle is an additional way of measuring working capital, which measures the number of days that funds are linked to inventories and receivables, minus the number of payment days deferred to

suppliers ( $CCC = DIO + DSO - DPO$ ). This cycle expresses, in other words, how many days it takes from the purchase of raw materials to the collection of receivables from the sale of the final product (Nobanee, 2009).

## 2.9 Working Capital and Profitability

In order to observe how management of working capital can affect the profitability of the company, emphasis must be placed on the cash flows of the company. More specifically, a larger cash conversion cycle may indicate that a company's sales are increasing and that the company can compete with loose credit policies or high stocks. Conversely, a higher cash conversion cycle can actually hurt a company's profitability by increasing the time that cash is tied to the non – interest bearing accounts of those accounts receivable. This indicates what a company must "sacrifice" in order to have either the corresponding flexibility in sales or the observance of specific economic policies (Nobanee, 2009).

## 2.10 Working Capital Calculation

Most companies, depending on the industry in which they belong, have invested a significant percentage of their capital in activities that may be subject to working capital. The required amount invested can be calculated using the net working capital method. However, it should be emphasized that cash, marketable securities, overdrafts and debts to banks, can't be considered as part of these operations, because they are considered as purely financial concepts. The required working capital can be calculated from the following formula:

$$\text{Working Capital} = \text{NWC} - \text{NBC} \text{ (Rafuse, 1996)}$$

Where WC is working capital, NWC is the net working capital and ΚΚΚ είναι το καθαρό κεφάλαιο κίνησης και NBC is the net cash balance.

NBC can be calculated with cash, commercial titles, withdraws and payable bonds.

Rafuse (1996), identified that the concept of requirement is mainly determined by four key variables. These variables are a) the accounts receivable, b) the reserves, c) the accounts payable and d) the net inflows. Finally, the functions of the company that affect them is the technology of the company, the managerial (operational) efficiency and the level of sales.

## 3. Net Working Capital

The investment required for receivables, reserves and cash is generally called working capital or gross working capital. Ideally, on the part of lenders, current liabilities should cover most of the financing for current assets and the rest of the shareholders (Padachi, 2006). Working capital, i.e. the part that can be optimized and influenced by the company's activities, is the accounts receivable, inventories and accounts payable. Other accounts such as cash, marketable securities, prepayments and all other current liabilities, are an economic decision of the company and have little to do with the company's own activities (Mathuva, 2015).

The more a business connects its assets to its working capital, the better for its liquidity. An optimal level of working capital could be considered as a level where a balance between risk and efficiency is achieved (Gul, et al., 2013). In the event that net working capital is negative (ie liabilities exceed assets), net working capital is financed with short-term capital, which can significantly increase borrowing costs (Kieschnick et al. 2006).

### 3.1 Net Working Capital and Liquidity

By using the cash conversion cycle, the management of working capital will ensure that sufficient funds are available for the company's liquidity and that these funds will be properly disposed of (Wang, 2002).

For liquidity management, the cash conversion cycle is suggested as the most dynamic tool. The larger the cash conversion cycle, the higher the required liquidity growth rate and vice versa, the smaller the cash conversion cycle, the lower the required liquidity level. The company must carefully reconsider whether to extend the credit period to launch a new product or, conversely, try to keep the comparative credit periods. In addition, the company must use a financial value – added approach to these decisions, in an effort to maximize shareholder value (Anjum & Malik, 2013).

In addition, working capital can be used to normalize liquidity when companies are trying to maintain a certain level of fixed (capital) investment. This means that companies can make short – term liquidity possible, by adjusting working capital without having to limit fixed investment (Wang, 2002).

Anjum & Malik, (2013), consider that conventional liquidity ratios do not substantially record the company's liquidity situation, as capital is linked to working capital. In essence, companies, especially the smaller ones, should try to focus on the cash flow cycle to maximize their short-term operating liquidity. Focusing on statistics at the end of the period may worsen the company's financial situation.

## 4. Cash conversion cycle

According to Attari & Raza, (2012), the cash conversion cycle (CCC) is a measurement of the time period (measured in days) that a company needs to convert its investments into reserves and other resources into cash flows (cash) from sales.

The method of calculating the cash conversion cycle (CCC) is as follows:  $CCC = DSI + DSO - DPO$ .

### 4.1 Cash conversion cycle and profitability

The first attempt to quantify working capital management, was made by Gitman in 1974, who introduced the concept of cash conversion cycle by indicating how many days the company had to accept cash collection from the purchase of raw materials (Farris et al. 2002). The problem with this measurement is that it is often impossible to find enough data to conduct a study, as detailed account balances are required for different types of stocks, such as raw materials, semi-finished and finished products. Therefore, the clean trading cycle was created, which adjusts the various elements of the cash conversion cycle depending on the company's sales (Zeidan & Anshapir, 2017). Deloof (2003), Awunyo-Vitor & Angmor (2013) and Anser & Malik (2013), measured the profitability of European companies based on gross operating income, which is defined as sales minus the cost of cash sold and this is divided by the total assets minus the financial assets. Deloof uses the cash conversion cycle as a comprehensive measure of working capital management. He has defined the cash conversion cycle (CCC) as follows:

$$\begin{aligned} & \text{Cash conversion cycle} \\ &= \text{no. of accounts receivable days} + \text{stock count days} - \text{no of accounts payable} \end{aligned}$$

With regards to control variables, it uses the sales growth rate (sales growth), the financial debt ratio, the fixed financial assets ratio to the total financial assets (fixed financial assets) and the volatility of the net operating income (variability defines the standard deviation of net operating income for the period 1991-96) (Deloof, 2003) (II, & Hutchison, 2003). They concluded that most companies have a high level of cash invested in working capital, so it is expected that companies will be able to manage working capital in order to significantly affect their profitability. He also noted a significant

negative relationship between gross operating income and the number of days accounts receivable, stocks and accounts paid to Belgian companies. In addition, it is pointed out that reducing the number of days accounts receivable and inventories to a minimum possible point, can create value to shareholders. The view that less profitable businesses are waiting longer to pay their dues is confirmed by the study (Deloof, 2003). Panigrahi (2013), in a similar study introduced other variables such as sales growth, fixed financial asset index and financial debt ratio and finally, he found out that there is a negative relationship between cash flow and profitability.

#### **4.2 The effect of net commercial cycle in profitability**

Erasmus (2010), Afza & Nazir (2007) have shown that shorter net trading cycles are usually associated with higher profitability and vice versa (Erasmus, 2010) (Afza, & Nazir, 2007).

The most important variables for managing working capital are the cash conversion cycle, the weighted cash conversion cycle and the net trading cycle. The net trading cycle is basically a calculation of the percentage of the simple cash conversion cycle. This means that each element of the simple cycle is converted to a percentage, dividing it by the total sales. In this way, the various elements are additional and at the same result have concluded the researchers Erasmus (2010), Baños-Caballero, García-Teruel & Martínez-Solano (2014).

Various surveys have used a correlation analysis between net turnover, profitability (sales performance and asset performance) and stock market adjustment returns (adjusted for risk based on the Alpha and Treynor index). In addition, it has been found that companies with a larger net turnover also have more leverage, which means that they need to finance their activities (especially working capital) by borrowing (Erasmus 2010), (Kaldor 1940), (Afza, & Nazir 2007).

### **5. Literature review**

The relationship between business capital management and business profitability is examined by Professor Marc Deloof in a sample of 1,009 major Belgian non-financial companies during the period 1992-1996. Trade credit policy and inventory policy are measured by the number of account receivables, accounts payable and inventories. The cash conversion cycle is used as a complete working capital management measure. The results show that running a business can increase profitability by reducing the number of days of accounts receivable and stocks. In addition, less profitable companies wait longer to pay their bills (Deloof, 2003).

The aim of the research of Juan García-Teruel and Martinez-Solano presented in their paper is to provide empirical evidence on the effects of working capital management on the profitability of a sample of small and medium size Spanish companies. The authors gathered data on a group of 8,872 small and medium size enterprises for the period 1996-2002. They examined the effects of working capital management on the profitability of these companies using the methodology of the table data. The results have shown that management can create value by reducing stocks and the number of days for which their accounts are excellent. The aim is to ensure that the relationships resulting from the analysis are due to the effects of the cash flow conversion cycle on business profitability and not the other way around (Juan García-Teruel & Martinez-Solano, 2007).

The purpose of the study by Samiloglu and Demirgunes (2008) is to analyze the effect of working capital management on business profitability. According to this goal, in order to take into account the statistically significant relationship between profitability and the components of the cash conversion cycle, a regression model is used, a sample consisting of companies listed on the Istanbul Stock Exchange (ISE) for the period 1998-2007. The empirical conclusions of the study show that the period

of receipt of receivables, the period of inventory and leverage negatively affect the profitability of companies while growth (in sales) positively affects their profitability.

Uyar (2009) collected data from the financial statements of listed companies on the Istanbul Stock Exchange for the year 2007 and presents benchmarks for companies in order to assess the performance of the CCC.

The study of Nobanee et al. (2011) explores the relationship between the cash conversion cycle and profitability for Japanese companies, where the organizational structure is completely different from that of American companies. Most of the Japanese companies were found to be affiliated through corporate groups.

It becomes clear that the cash conversion cycle (CCC) is considered a useful measure for the effective management of a company's working capital and especially for the management of its cash and cash equivalents. The following study was conducted to examine the relationship between the cash conversion cycle and the size and profitability of companies in the four specific construction sectors listed on the Karachi Stock Exchange, namely in the automotive and parts sector, cement, chemicals and food producers. The data were collected from the annual reports of 31 companies included in the sample, from the total companies of the relevant sectors, i.e. 143, for the period 2006-2010. Data analysis was performed by using ANOVA and Pearson One-Way correlation techniques. The lowest average value of the cash conversion cycle length is in the cement industry, averaging -52.38 days and the highest average is in the automotive industry, averaging 73.72 days. A similar study by Attari & Raza (2012), in the four specific construction sectors listed on the Karachi Stock Exchange, found a significant negative correlation between the cash conversion cycle and the size of the business, in terms of total assets, but also negative correlation between cash conversion cycle and profitability, in terms of return on total assets.

In a sample of 30 companies listed on the Nairobi Stock Exchange (NSE) for the periods 1993-2008, by Mathuva (2015), a positive relationship is found between the time it takes the company to pay its creditors (average payment period) and profitability. This means that the longer the company takes to pay its creditors, the more profitable it is.

## 6. Data collection and methodology

The purpose of this paper, as mentioned above, is to study the influence of working capital on the profitability of a sample of French PLCs. The data concerns 80 French companies and their financial data refer to the period from 2020 to 2024 and the data were obtained from STATA as well as the Paris Stock Exchange.

The present work will follow a combined methodology regarding the previous bibliographic review. The least squares method for regression and the ANOVA analysis method will be used. Specifically, elements of the Balance Sheet and Income Statement will be used to calculate inventory turnover (DSI), accounts receivable (DSO) and accounts payable (DPO), which in turn will lead to the calculation of the cash conversion cycle (CCC), which will be the independent variable of both models.

In order to investigate the effect of working capital on profitability, the following two models will be created.

$$\text{Sales} = s * \text{CCC} + \text{constant} + \varepsilon \quad (1)$$

$$\text{Operating Income} = t * \text{CCC} + \text{constant} + \varepsilon \quad (2)$$

s, t: regression coefficients

The first model, as shown in equation (1), has as its dependent variable Sales and as an independent variable the cash conversion cycle (CCC). The coefficient “s” is the regression coefficient, the term constant is the model constant and e represents the residuals of the regression. In equation (2), the dependent variable is the operating income (Operating Income) and the independent variable is the cash conversion cycle (CCC). The coefficient “t” is, in this model as well, the regression coefficient, the term constant is the constant of the model and “ε” indicates the residuals of the regression.

In addition, the basic tests of a regression model will be performed. More specifically, the tests of autocorrelation, heteroscedasticity as well as the control of statistical significance will be carried out. Finally, the analysis will be performed with the GRETl program.

| Pearson factor         |       |
|------------------------|-------|
| Sales - CCC            | -0,01 |
| Pearson rate           |       |
| Operating income - CCC | -0,01 |

## 7. Analysis

### 7.1 Descriptive statistics

The table below shows the descriptive data of the variables that have been selected in order to examine the influence of working capital on the profitability of 80 French companies PLCs during the 2020–2024 period. These variables, in turn, are the inventory turnover rate (DSI), the accounts receivable turnover rate (DSO), the accounts payable turnover rate (DPO), the cash conversion cycle (CCC), the sales (Sales) and operating income (Operating Income). The descriptive elements, which have been calculated in order, are the mean value (mean), the median, the standard deviation, the minimum (min) and the maximum value (max). The average value of accounts receivable is quite high and therefore leads to high levels of the cash conversion cycle. This means that companies are slow to recover their original outflows, thus creating potential liquidity problems.

Table 1 – Descriptive statistics of variables

|                 | Mean       | Median      | S.D.       | Min         | Max        |
|-----------------|------------|-------------|------------|-------------|------------|
| DSI             | 668.3      | 78.29       | 10498      | 0.1053      | 2.298e+005 |
| DSO             | 3115       | 71.30       | 56410      | 0.06609     | 1.236e+006 |
| DPO             | 716.8      | 92.93       | 6860       | 5.022       | 1.404e+005 |
| CCC             | 3067       | 101.6       | 56574      | -4.613e+004 | 1.235e+006 |
| Sales           | 1.451e+009 | 1.869e+007  | 7.506e+009 | 6380        | 6.658e+010 |
| OperatingIncome | 9.245e+007 | -5.915e+004 | 4.700e+008 | -7.310e+008 | 4.062e+009 |

### 7.2 Sales and Cash Conversion Cycle

The below table presents the results that resulted from the regression of the cash conversion cycle with sales. The resulting equation is as follows:

$$\text{Sales} = -1.369,42 * \text{CCC}$$

Table 2 – Regression analysis

Model 1: Pooled OLS, using 480 observations

Included 6 cross-sectional units

Time-series length = 80

Dependent variable: Sales

|                    | coefficient | std. error         | t-ratio   | p-value  |
|--------------------|-------------|--------------------|-----------|----------|
| const              | 1.45534e+09 | 3.43459e+08        | 4.237     | 2.72e-05 |
| CCC                | -1369.42    | 6068.41            | -0.2257   | 0.8216   |
| Mean dependent var | 1.45e+09    | S.D. dependent var | 7.51e+09  |          |
| Sum squared resid  | 2.70e+22    | S.E. of regression | 7.51e+09  |          |
| R-squared          | 0.000107    | Adjusted R-squared | -0.001985 |          |
| F(1, 478)          | 0.050924    | P-value(F)         | 0.821560  |          |
| Log-likelihood     | -11595.29   | Akaike criterion   | 23194.58  |          |
| Schwarz criterion  | 23202.93    | Hannan-Quinn       | 23197.86  |          |
| rho                | 0.908362    | Durbin-Watson      | 0.183179  |          |

From the sign of the exogenous variable it seems that the cash conversion cycle has a negative effect on sales. In other words, these two variables are inversely related. However, according to the Spearman correlation coefficient (rho) the two variables have a strong positive correlation with each other as the coefficient is quite close to the unit (rho = 0.908362). That is, their relationship from this factor emerges as proportional.

Due to this fact, the statistical significance check of the coefficient resulting from the regression with the calculated P-value will be performed. 95% with  $\alpha = 5\%$  is selected as the confidence level. The zero and alternative hypothesis of the control are listed below.

$H_0$ : The rate is not statistically significant

$H_1$ : The rate is statistically significant

The p-value of CCC is 0,82.

$$P - value = 0,82 > \alpha = 0,05$$

Since the p value is much greater than  $\alpha$  the null hypothesis must be accepted. Therefore, the negative coefficient (-1.369,42) resulting from the regression is not statistically significant and there is no strong indication of the type of correlation between the two variables. However, the only substantive result is that there is a lack of linear relationship between the two variables.

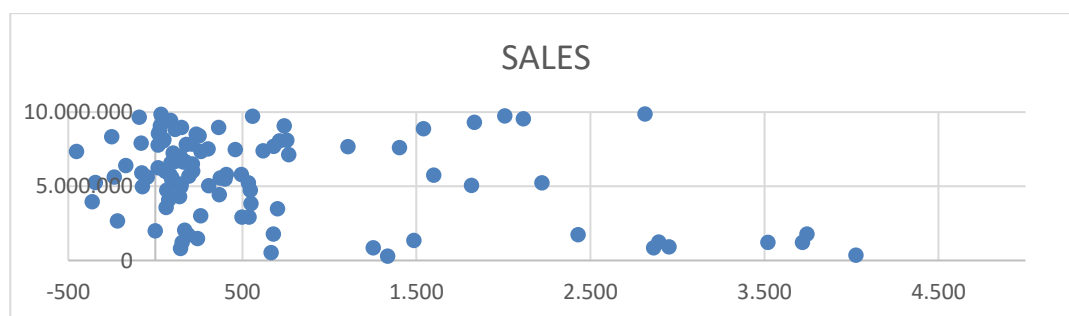


Figure 1 - Diagram Sales dispersion – Cash conversion cycle CCC

Even from the scatter plot between the two variables it seems that there is no linear correlation.

For this reason even the Pearson correlation coefficient, which is suggested through the literature review, is close to zero.

*Table 3 – Correlation rate Pearson*

| Pearson factor |       |
|----------------|-------|
| Sales - CCC    | -0,01 |

In the below table the P-Value has been calculated to perform the heteroskedasticity test. The existence of heteroskedasticity is a key prerequisite in the application of regression analysis, including analysis of variance, as it can invalidate important statistical tests that assume that the model errors are indivisible and uniform and therefore their variations do not vary according to the model. For example, while the standard least squares estimator is still unbiased in the presence of heteroskedasticity, it is ineffective because actual variance and covariance are underestimated. Similarly, in tests for differences between subpopulations using a position test, some standard tests assume that the variations within the groups are equal. 95% with  $\alpha = 5\%$  is selected as the confidence level.

*Table 4 - Heteroskedasticity test*

```
White's test for heteroskedasticity -
Null hypothesis: heteroskedasticity not present
Test statistic: LM = 0.065481
with p-value = P(Chi-square(2) > 0.065481) = 0.96779
```

Therefore, the null and the alternative hypothesis for control are formulated as follows:

H0: There is homoskedasticity

H1: There is heteroskedasticity

The p-value of heteroscedasticity White is 0,96.

$$P - \text{value} = 0,96 > \alpha = 0,05$$

Since the value of p is greater than  $\alpha$  the null hypothesis must be accepted. Consequently, there is homoscedasticity in the observations of the variables and the possibility of canceling some controls due to the existence of heteroscedasticity is reduced.

The check for the existence of autocorrelation of the residues will be done with the statistical data of Durbin - Watson and the resulting P-Value. 95% with  $\alpha = 5\%$  is selected as the confidence level. The assumptions for the audit are as follows:

H0: There is no autocorrelation

H1: There is autocorrelation

The resulting p-value of the resulting Durbin-Watson autocorrelation test is infinitesimal and close to zero.

Because the p-value is much less than  $\alpha$ , the null hypothesis must be rejected and the alternative accepted. In addition, there is autocorrelation in the regression residues and this is an indication that the residues are not just white noise but may be missing data and important information.

Table 5 – Autocorrelation test

Durbin-Watson statistic = 0.183179  
p-value is "very small" (the Imhof integral could not be evaluated so a definite value is not available)

Analysis of variance (ANOVA) provides a statistical test of whether two or more mean values of a population are equal and therefore generalizes the t-test beyond two mean values. 95% with  $\alpha = 5\%$  is selected as the confidence level. The assumptions for the audit are as follows:

H0: There is no significant statistical influence

H1: There is significant statistical influence

The resulting p-value of t test for variance analysis (ANOVA) is 0.82.

$$P - value = 0,82 > \alpha = 0,05$$

Table 6 – ANOVA

Analysis of Variance:

|            | Sum of squares | df  | Mean square  |
|------------|----------------|-----|--------------|
| Regression | 2.87498e+018   | 1   | 2.87498e+018 |
| Residual   | 2.69862e+022   | 478 | 5.64565e+019 |
| Total      | 2.69891e+022   | 479 | 5.63446e+019 |

$R^2 = 2.87498e+018 / 2.69891e+022 = 0.000107$   
 $F(1, 478) = 2.87498e+018 / 5.64565e+019 = 0.0509239$  [p-value 0.8216]

Since the p value is greater than  $\alpha$  the null hypothesis must be accepted. Therefore, there is no statistically significant influence between the two variables.

### 7.3 Operating Income and Cash Conversion Cycle

The table below presents the results obtained from performing the regression of the cash conversion cycle with operating income. The resulting equation is as follows:

$$\text{Operating Income} = -88,90 * \text{CCC}$$

Table 7 – Regression analysis

| Model 3: Pooled OLS, using 480 observations |             |                    |           |          |
|---------------------------------------------|-------------|--------------------|-----------|----------|
| Included 6 cross-sectional units            |             |                    |           |          |
| Time-series length = 80                     |             |                    |           |          |
| Dependent variable: OperatingIncome         |             |                    |           |          |
|                                             | coefficient | std. error         | t-ratio   | p-value  |
| const                                       | 9.27268e+07 | 2.15033e+07        | 4.312     | 1.96e-05 |
| CCC                                         | -88.9001    | 379.932            | -0.2340   | 0.8151   |
| Mean dependent var                          | 92454177    | S.D. dependent var | 4.70e+08  |          |
| Sum squared resid                           | 1.06e+20    | S.E. of regression | 4.70e+08  |          |
| R-squared                                   | 0.000115    | Adjusted R-squared | -0.001977 |          |
| F(1, 478)                                   | 0.054751    | P-value (F)        | 0.815093  |          |
| Log-likelihood                              | -10265.28   | Akaike criterion   | 20534.55  |          |
| Schwarz criterion                           | 20542.90    | Hannan-Quinn       | 20537.83  |          |
| rho                                         | 0.807091    | Durbin-Watson      | 0.385634  |          |

Due to this, the statistical significance check of the coefficient resulting from the regression with the calculated P-value will be performed. 95% with  $\alpha = 5\%$  is selected as the confidence level. The zero and alternative hypothesis of the control are listed below.  $H_0$ :

$H_1$ : The rate is statistical important

The p-value of CCC is 0,81.

$$P - value = 0,81 > \alpha = 0,05$$

Since the value of p is much greater than  $\alpha$  the null hypothesis must be accepted. Therefore, the negative coefficient (-93.83) resulting from the regression is not statistically significant and there is no strong indication of the type of correlation between the two variables. However, the only substantive result is that there is a lack of linear relationship between the two variables.

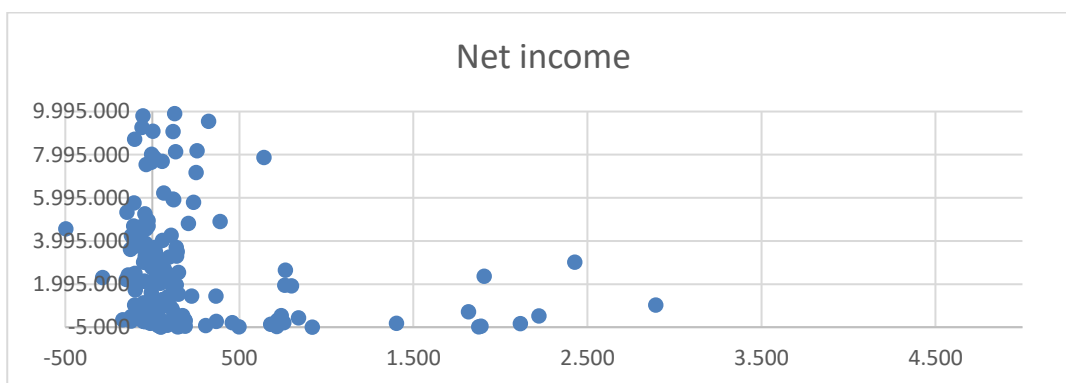


Figure 2 – Dispersion of operating income – CCC

Even from the scatter plot between the two variables it seems that there is no linear correlation.

For this reason even the Pearson correlation coefficient, which is suggested through the literature review, is close to zero.

Table 8 – Correlation rate Pearson

| Pearson rate           |       |
|------------------------|-------|
| Operating income - CCC | -0,01 |

In the table below, the P-Value has been calculated to perform the heteroscedasticity test 95% with  $\alpha = 5\%$  is selected as the confidence level.

Table 9 – Heteroscedasticity test

White's test for heteroskedasticity -  
 Null hypothesis: heteroskedasticity not present  
 Test statistic: LM = 0.103375  
 with p-value =  $P(\text{Chi-square}(2) > 0.103375) = 0.949625$

The zero and alternative hypothesis for control are as follows:

H<sub>0</sub>: There is homoscedasticity

H<sub>1</sub>: There is heteroscedasticity

The p-value of heteroscedasticity White test is 0,949.

$$P\text{-value} = 0,949 > \alpha = 0,05$$

Since the value of p is greater than  $\alpha$  the null hypothesis must be accepted. Consequently, there is homoscedasticity in the observations of the variables and the possibility of canceling some controls due to the possibility of heteroscedasticity is reduced.

The check for the existence of autocorrelation of the residues will be done with the statistical data of Durbin - Watson and the resulting P-Value. 95% with  $\alpha = 5\%$  is selected as the confidence level. The assumptions for the audit are as follows:

H<sub>0</sub>: there is no autocorrelation

H<sub>1</sub>: there is autocorrelation

The resulting p-value of the resulting Durbin-Watson autocorrelation test is close to zero.

Table 10 – Autocorrelation check

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Durbin-Watson statistic = 0.385634  
 p-value is "very small" (the Imhof integral could not  
 be evaluated so a definite value is not available)

Since the p-value is greater than  $\alpha$ , the null hypothesis must be accepted. Therefore, there is no autocorrelation in the regression residues and this is an indication that the residues are just white noise.

The assumptions for the audit are as follows:

H<sub>0</sub>: There is no statistical significant influence

H<sub>1</sub>: There is statistical significant influence

The p-value from the ANOVA analysis, is 0,81.

$$P\text{-value} = 0,81 > \alpha = 0,05$$

Table 11 – ANOVA

Analysis of Variance:

|            | Sum of squares | df  | Mean square  |
|------------|----------------|-----|--------------|
| Regression | 1.21163e+016   | 1   | 1.21163e+016 |
| Residual   | 1.0578e+020    | 478 | 2.21297e+017 |
| Total      | 1.05792e+020   | 479 | 2.2086e+017  |

$R^2 = 1.21163e+016 / 1.05792e+020 = 0.000115$   
 $F(1, 478) = 1.21163e+016 / 2.21297e+017 = 0.0547512$  [p-value 0.8151]

95% with  $\alpha = 5\%$  is selected as the confidence level.

Since the value of p is greater than  $\alpha$  the null hypothesis must be accepted. Therefore, there is no statistically significant influence between the two variables.

## 8. Conclusions

This study examined the relationship between working capital management and profitability using data from 80 French PLCs during the period 2020–2024. The post-COVID period introduced unique liquidity pressures and operational challenges across industries. The data collected concerned 80 French companies and presented data on inventory accounts, accounts receivable, accounts payable, sales, net sales and cost of goods sold

After the presentation of the descriptive statistics of the variables, a regression analysis was performed on the relationship between the cash conversion cycle and first stage sales and then the cash conversion cycle with the operating income of the companies. The results, in general, do not seem to converge.

The results regarding the pair sales - cash conversion cycle show that there is an almost weak correlation between the variables. This conclusion came mainly from the Pearson correlation coefficient. The negative correlation resulting from the regression was statistically insignificant and in combination with the scatter plot the two variables had no linear relationship at all.

On the other hand, the results of the pair of variables operating income - cash conversion cycle, seem to show a negative correlation between them. While the Pearson correlation coefficient is almost zero and the exogenous variable coefficient is statistically insignificant, there appears to be a negative correlation between the two variables.

Taking into account all the above, and based on the selected sample, it appears that the profitability of French companies has from negligible to negative relationship with the cash conversion cycle and consequently with working capital.

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## **Digital and virtual economy – the evolution of cryptocurrencies**

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### **Abstract**

This paper examines the historical evolution of money, with a particular emphasis on the advent of virtual currencies, especially cryptocurrencies. The emergence of virtual currencies marks a significant shift in the evolution of money, as a transformative element in the modern digital economy, the rise of virtual currencies reflects a complex interplay between the exponential growth of transaction volumes, developments in digital technologies, and the evolving needs of modern economies. The study analyzes the socio-economic parameters that led to their emergence and potentially adoption and the demand for alternatives to traditional monetary systems. In addition, the paper assesses the current economic and institutional responses to the growing influence of digital currencies, including the development of central bank digital currencies (CBDCs) and the adaptation of legal and regulatory frameworks to accommodate them. By placing these developments in the broader context of monetary evolution, this research contributes to a deeper understanding of the definition of money in an increasingly virtual economic landscape and offers insights into the course of monetary innovation in the global economy.

**Keywords:** *Digital Economy, Virtual Currency, Cryptocurrency, Monetary Evolution, Central Bank Digital Currencies (CBDCs), Financial Technology.*

# Workplace Diversity Disclosure in US-based Public Companies

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## Abstract

In 2020, the U.S. Securities and Exchange Commission's (SEC) amended Regulation S-K, requiring firms to disclose "material human capital resources" in their annual 10-K filings (SEC, 2020). This principles-based rule is the first systematic, regulator-mandated inclusion of DEI (diversity, equity and inclusion) information in financial filings in the USA. Prior research shows that corporate DEI disclosure has become a vital performance metric among socially responsible investors (Chiu, 2022), but the principles-based nature introduces variability in disclosure quality, and raises concerns about a lack of comparability between peer firms (Demers et al., 2022).

While contemporary research on the new rule has largely focused on broader human capital disclosures, this study focuses on workplace diversity, which implies the presence and inclusion of individuals with a wide range of characteristics and backgrounds within an organization. For example, Armache (2012) defines disclosure on workplace diversity as reporting on the diversity of the workforce with regard to age, culture, gender, sexual orientation and physical and mental ability. Scholars argue that managing workplace diversity is a business case, because workplace diversity has economic benefits such as assisting companies in attracting and retaining a wider talent pool, achieving higher employee job satisfaction, and ultimately increasing business profitability and corporate innovation (Harter et al., 2002).

This study examines the information content of workplace diversity disclosures of S&P 500 firms from 2019 to 2022, i.e., pre- and post-SEC regulation. Consistent with some other recent studies (e.g., Vasarhelyi et al., 2023), and because a manually conducted content analysis would pose challenges and is time-consuming, this study employs large language models (LLMs) to automate the content analysis of the ESG reports. A tailored prompt was developed and used for ChatGPT v. 4.0. The conducted content analysis generated fifteen binary indicators of diversity-related disclosure, which we organize into three categories: leadership diversity, workforce composition, and diversity-related initiatives. The approach through multiple methods, including manual verification and inter-rater reliability tests.

This study aims to contribute to the literature on human capital disclosure, more specifically workplace diversity, and the AI literature on the use of generative artificial intelligence (Gen AI). First, previous research on human capital-related disclosures is still scarce. This study is among the first comprehensive analyses of corporate workplace diversity disclosures under the SEC's new reporting requirements. Second, this research increases the understanding of how Gen AI can assist in automating corporate sustainability information extraction and analysis. Finally, from a practical standpoint, the findings provide insightful information on contemporary corporate practice. This

study would be of interest to managers responsible for sustainability or HR reporting, but likely also other stakeholders such as investor, analysts, and auditors.

**Keywords:** *workplace, diversity, corporate disclosure. ChatGPT, content analysis*

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## **Evaluating the impact of fintech on sustainable entrepreneurship with blockchain technology as a mediator**

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### **Abstract**

**Introduction:** FinTech gives entrepreneurs the environment they need to make investments and payments for research, goods, and services in the most convenient way possible. One could also argue that FinTech innovation is one of the factors propelling company sustainability and outlook expansion in the current globalized marketplace.

**Purpose:** By bridging the gap between the market and instant access to financing, fintech is revolutionizing entrepreneurship. Numerous benefits, such as easier access to resources, lower costs, and improved customer satisfaction, are offered to entrepreneurs. With blockchain technology acting as a mediator, this paper focuses on the connection between FinTech and its effects on sustainable enterprise. It then examines the different issues that authors from all over the world have covered in their published works. Hence, this research has concentrated on evaluating the role and impact of FinTech industry on sustainable entrepreneurial business.

**Need for the Study:** Customers, researchers, and corporate managers have begun evaluating financial services online, and post-pandemic technology has created enormous potential in the financial sector, allowing businesses to innovate their business methods. The current study intends to investigate the ways in which blockchain enhances FinTech's function in sustainable entrepreneurship.

**Methodology:** The study's objectives were met through a comprehensive evaluation of the literature, which included bibliographic analysis. A mixed technique of data collecting was employed to conduct research, with primary data obtained via an online survey and secondary data collected via internet publications and peer-reviewed journals. To obtain primary data, an online poll was conducted with 71 corporate managers recruited from the social networking platform LinkedIn. Secondary data were acquired from the online databases Scopus, Web of Science, and Google Scholar, which were published between January 2022 and March 2025.

**Findings:** The findings of the study have underlined the numerous effects that Fintech has had on entrepreneurship firm in the worldwide market and the reason why it is such a crucial factor for growth. It is observed that since the introduction of the first blockchain database in corporate entrepreneurship, a lot of effort has been undertaken, but it is still at a primitive level. Also, it is seen that a significant number of string-specific high-quality research articles published in the Elsevier/Scopus and Clarivate Analytics/WoS databases since 2023 were written by writers from Asia, especially China and India.

**Practical Implications:** The current study illustrates the different ways that the idea of "FinTech-Blockchain-Sustainable Entrepreneurship" needs to be further investigated, and that creative, foolproof solutions must be developed to overcome the obstacles and improve the standing and operations of businesses in Industry 5.0.

**Keywords:** *Fintech, Entrepreneurship, Technology, Sustainability*

## 1. Introduction

FinTech technology enables business transactions in a cost-effective manner. When digital and physical payment methods are integrated, various account transactions can be handled by a single interference. FinTech has aided entrepreneurs by making resources more accessible and expanding the entrepreneurship industry (Kathuria et al., 2024). On the other hand, FinTech technology's implications for entrepreneurship have guaranteed both the viability of businesses and the customization of business procedures (Gupta and Jindal, 2024).

FinTech technology also propels disruptive innovation in entrepreneurship. The fundamental tactic used by entrepreneurs to develop a viable and prosperous business opportunity in the global marketplace is the financial process (Shalender et al., 2023). FinTech's tech-savvy strategy enables entrepreneurs to compete in the global marketplace. The study will assess how FinTech affects business entrepreneurship.

### 1.1. The fintech-sustainable entrepreneurship ecosystem

The worldwide entrepreneurship industry places a high priority on FinTech technology because of the development of digital technologies and the shifting demands and expectations of consumers (Muthukannan et al., 2021). One of the key elements influencing the adoption of FinTech in entrepreneurship enterprises is addressing and reducing the obstacles to breaking into a new market segment (Basdekidou and Papapanagos, 2023).

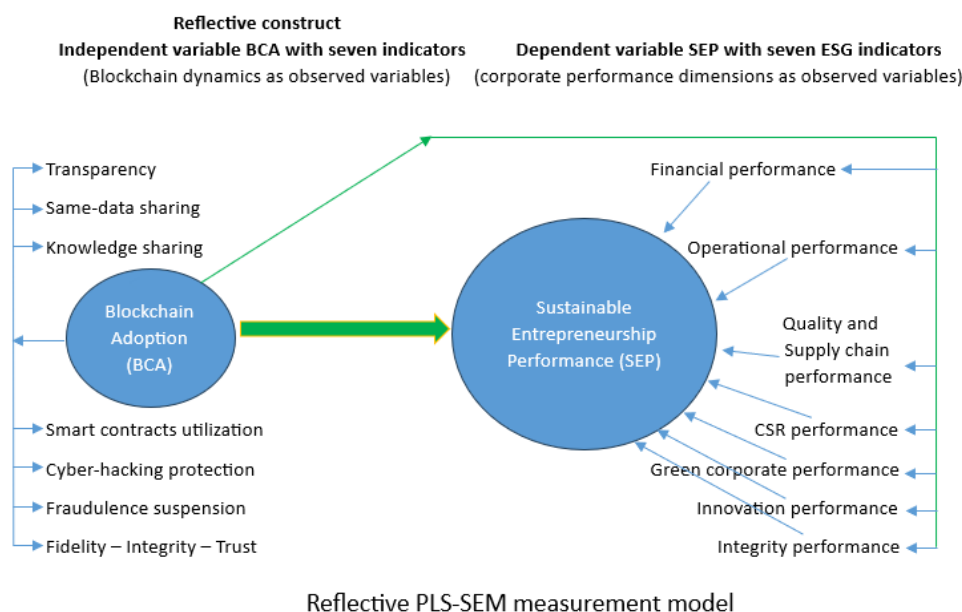
Another key goal for international entrepreneurial companies is to take advantage of funding opportunities in order to further develop their enterprises. Along with securely storing the records in a digital format, digital banking procedures can be regarded as the most secure transaction solution for corporate companies (Gupta and Jindal, 2024). Consequently, security plays a significant role in the FinTech entrepreneurial industry's transformation.

### 1.2. Sustainable entrepreneurship and fintech/blockchain trends

According to Remolina (2019) and Basdekidou and Papapanagos (2025), the latest FinTech trends - such as open banking, the Internet of Things, artificial intelligence (AI) and machine learning, neo-banking, and the most well-liked buy now pay later plans- have a significant impact on the global business platform. Furthermore, the most successful applications of FinTech technology in global business include biometrics and alternative lending.

According to the proposed Blockchain Adoption (BCA) - Sustainable Entrepreneurship Performance (SEP) model, the most advantageous aspects of FinTech developments for global businesses are transparency, same-data sharing, knowledge sharing, smart contracts utilization, cyber-hacking protection, fraudulence suspension, fidelity, integrity, and trust (Fig. 1) (Basdekidou and Papapanagos, 2024a). Blockchain is the most significant and successful FinTech trend for international commercial platforms (Basdekidou and Papapanagos, 2024b). To prevent any loss of business, blockchain technology is implemented as a digital ledger that records and detects transaction faults (Kathuria et al., 2024).

### The proposed Outer (Measurement) Model



#### Theoretical considerations:

(a) Direction of causality between latent construct and items: "Causality from construct to items"  
 (i.e., a change in the reflective construct BCA causes a change in the 14 indicators).

(b) Items' characteristics: "The BCA construct manifests items."

(i.e., the items share a common theme (BCT dynamic, performance), items are interchangeable, and removing or adding an item does not change the conceptual domain of the BCA construct).

Fig. 1. The proposed BCA- SEP Model.

### 1.3. Sustainable businesses and fintech: a systematic review and future directions

There are many benefits to using FinTech solutions in companies that have sustainable operations (Basdekidou and Papapanagos, 2024a). Furthermore, Arslam et al. (2022) claim that small enterprises operate more effectively when financial information are easily accessible. Likewise, another advantage of FinTech solutions is their flexible funding options for small business expansion. The range of payment methods available through FinTech transactions, such as digital wallets, debit cards, and credit cards, increases the likelihood that small businesses will grow internationally. The subsequent business execution plan for small enterprises in the global business market is also ensured by recording and recognizing the transaction information with FinTech and BCA solutions (Basdekidou and Papapanagos, 2024b).

Entrepreneurial businesses with modest infrastructure have changed their financial paradigm from traditional to digital, considering FinTech solutions to obtain operating finance, claim Vasile et al. (2021). Another goal of small firms using the digital platform of FinTech solutions to assess their profit is to lower transactional costs. Another factor driving the paradigm shift in small business finance is better cash flow management. The client experience during risk-free product or service purchases is also improved by streamlined payment processing (Singla et al., 2023). FinTech solutions for small business finance also contribute to increased security. Small firms' loyalty and trust have increased in the global marketplace, and they have developed a unique brand identity considering the implications of Fintech solutions (Hicham et al., 2023).

### 1.4. Objective of study

The goal of the study is to produce useful information about FinTech/BCA solutions for entrepreneurs and small businesses. Given the study's consistency, the research's goals are:

- to assess how FinTech and BCA affects entrepreneurship;
- to examine the elements that propel global FinTech entrepreneurship;
- to assess global FinTech trends for multinational enterprises;
- to look into the future views of FinTech and BCA solutions; and
- to determine the tactics of FinTech and BCA solutions for profitability in entrepreneurship firms.

## **2. Data and method**

### **2.1. Type of research used**

The research design refers to the methodological interpretation of research that includes tools and techniques for research execution. Identifying and addressing the problem of research is another beneficial aspect of research design.

A case-study research design has been used in this study to gain a thorough understanding of the problem while considering the practical context. The case study design can be used to assess the effect of FinTech on entrepreneurship businesses globally. Additionally, a variety of studies have been conducted to examine all viewpoints regarding the influence of FinTech on international entrepreneurship (Gupta and Jindal, 2024).

To finish the investigation, the mixed type employs both qualitative and quantitative methodologies. Only textual and non-numerical data are used in the qualitative approach, whereas only numerical data are used in the quantitative approach. As a result, both approaches have been successfully applied to give a comprehensive understanding of the topic.

### **2.2. Data collection and analysis techniques**

The process of gathering data is the most efficient way to support the purpose of the study. Primary and secondary data collecting methods are two categories of data collection procedures that are typically employed in a study. Both data gathering techniques, known as mixed methods, have been applied in this study.

The primary data gathering method, which uses surveys and interviews, denotes first-hand, authentic data sources (Kathuria et al., 2024). A sample size of 71 has been chosen for this study to administer the online survey. Conversely, the secondary data collection process makes use of pre-existing data from market reports, peer-reviewed journals, and websites. The likelihood of a more tangible study justification is increased by both numerical and non-numerical evidence facts.

Software called the Statistical Package for the Social Sciences (SPSS) has been used to analyze primary data to further justify the interpretation of the evidence and accomplish the study's objective. Similar to this, the researcher has employed thematic data analysis for secondary data analysis, which allows the researcher to freely express individual observations with the support of peer-reviewed journals to support the study (Gupta and Jindal, 2024).

The gathered data has been presented using a variety of themes, and some secondary data presented under the study's second theme has also been analyzed using Microsoft Excel.

## **3. Results**

### **3.1. Fintech profitability with entrepreneurial and institutional BCA strategies**

According to Basdekidou and Papapanagos (2023) emerging Fintech solutions for business financial breakthroughs and Fintech profitability are complementary. As a result, entrepreneurs have employed customers' perceptions (Nanos et al., 2024) and cloud computing adoption solutions to predict the companies' future profits (Nanos, 2023). For Fintech to be profitable, companies primarily prioritize customer-centric initiatives (Ajouz and Abuamria, 2023), BCA (Basdekidou and Papapanagos, 2024a), and Artificial Intelligence (AI) solutions, i.e. Blockchain and AI disclosure on financial performance (Shiyyab et al., 2023).

The most powerful and effective viewpoint for business owners guarantees a rise in demand for goods and services while taking risk-free payment methods into account is customer pleasure. To generate high-value financial benefits, fintech-savvy organizations are concentrating on innovation and competitiveness. However, another strategic application of entrepreneurial strategy is the utilization of high investment possibilities (Hurani and Abdel-Haq, 2025).

Numerous Fintech firms provide loans and other financial benefits to new businesses, increasing their ability to compete in highly competitive international marketplaces. Entrepreneurs' innovation strategy is also increasing the likelihood that their businesses will become financially profitable. The analysis of the break-even point for start-ups, which also aids in determining the risk factors for the financial execution of enterprises, is another successful tactic that entrepreneurial institutions have employed. Additionally, since the business's profitability margin stabilizes with a long-term investment, it suggests that the short-term investment objective is preferable than the long-term one (Cochrane, 2022). Nonetheless, new strategic Fintech solutions somewhat guarantee a certain profit margin for startups and small firms.

### **3.2. The fintech landscape worldwide**

North America, which is home to more than 12,600 financial technology companies and has modest growth from 2023, continued to dominate the global FinTech environment in 2024/2025. At the same period, with more than 9,450 businesses, Europe remained the second-largest fintech hub, while Asia-Pacific was home to 7,125 FinTechs (Statista.com, 2025).

Although the business expanded rapidly from 2008 to 2024, there was a noticeable drop in the number of new fintech formations after 2021. The United States cemented its leadership in the fintech sector by having over five times as many unicorns as the second-ranked United Kingdom in 2024 (Statista.com, 2025).

It is possible to forecast the future views of small and startup enterprises by considering the economic expansion of Fintech organizations. With the future securely set a profitability rate in mind, most businesses are implementing Fintech financial tactics. AI's impact on the Fintech industry also raises the likelihood of financial gain.

As a result, the number of Fintech users is expected to increase from 5.62 billion in 2023 to 7.17 billion in 2027 (Fig. 2) (Statista.com, 2025).

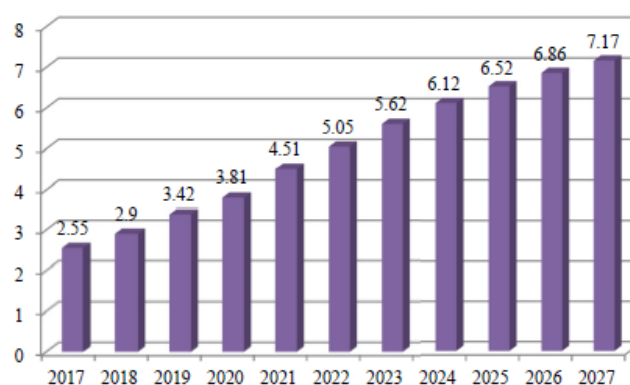


Fig. 2. Fintech Users Worldwide (2017–2027). Source: Statista.com (2025).

### 3.3. Fintech on sustainable entrepreneurship: AI, Big data, and BCA solutions

The greatest method to improve customer experience with AI and big data assistance is with a Fintech solution (Shiyyab et al., 2023). Customers' trust and loyalty toward start-ups are increased by assurances of privacy and safe payment transactions, which also improve the stability of firms. Transparency, smart-contracts utilization, innovation, risk-free transactions and knowledge sharing are some of the advantages of Fintech/BCA solutions for small enterprises (Fig. 1) (Basdekidou and Papapanagos, 2024a & 2025). Customers are more satisfied when using products or services from entrepreneurship enterprises when business procedures are customized by Fintech solutions (Khanal et al., 2023).

Unlike other traditional financial services, fintech/BCA solutions focus on reduced financial services costs (Basdekidou and Papapanagos, 2025). Fintech technology with BCA features can also establish how entrepreneurial institutions might increase efficiency. The most important viewpoint for small firms, especially entrepreneurial ones, is financial risk management, which is also demonstrated by the strategic implications of Fintech technology for these companies.

Developing FinTech solutions for financial operations can give start-ups a competitive edge and increase their visibility (Basdekidou and Papapanagos, 2024b). Additionally, businesses' sense of security are raised when financial services are delivered and used automatically using BCA solutions. Therefore, there are several reasons why Fintech and BCA are becoming more and more well-known among entrepreneurs and will do so in the future (Hurani and Abdel-Haq, 2025). Fintech and BCA will continue to have a favorable impact on the world of entrepreneurs, which will lead to a rise in their market adoption (Hicham et al., 2023).

### 3.4. FinTech on sustainable entrepreneurship: impact & outlook

The financial benefits that FinTech solutions offer businesses underscore the broader insights that entrepreneurship businesses will have in the future when taking the economy into account. By 2030, the FinTech industry is expected to generate \$1.5 trillion in sales annually, accounting for 2% of the worldwide market (BCG, 2025).

The economic growth of firms, including entrepreneurship businesses, reflects the efficacy of Fintech applications. The FinTech industry's annual growth rate is rising steadily, which is a noteworthy accomplishment for the Fintech businesses. The industry's total revenue in 2024 was 214.17 billion, as shown in Figure 3, and it is projected to reach 294.5 billion by 2027 (Statista.com, 2025).

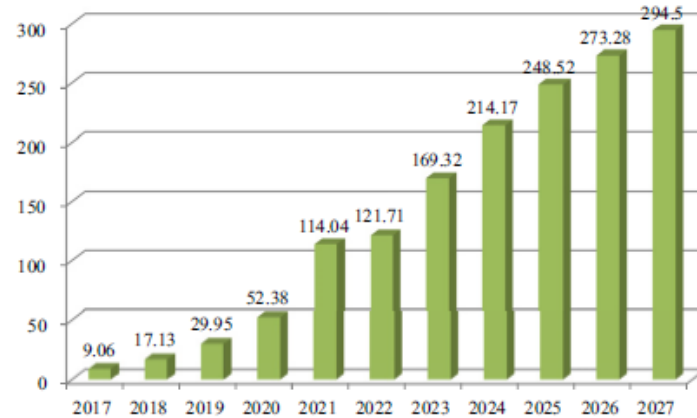


Fig. 3. Revenue of Fintech Industry Worldwide (2017–2027). Source: Statista.com (2025).

### 3.5. FinTech & BCA impact on sustainable entrepreneurship: descriptive statistics

The process of providing a clear and meaningful summary of numerical and categorical data is known as “*Descriptive Statistics*”. It entails describing important aspects of the data using a variety of metrics, including center, variability, shape, and position metrics. Descriptive analysis utilizes a better sense of the collected data. In our case descriptive statistics (Table 1) was done with the help of the IBM SPSS software to understand the “characteristics” and “features” of the primitive data that were collected using the survey method.

*Mean* and *Standard Deviation* (Std. dev.) are the two critical factors with the *mean* value for all the statements being around 4 (“Agree”) and the *Std. dev.* being between 0.95 and 1.30. Hence, the *mean* value signifies that most of the participants agreed with the statement, since “4” was the value that was assigned to the “Agree” option on the Likert scale (Strongly Agree: 5, Agree: 4, Neutral: 3, Disagree: 2, and Strongly Disagree: 1).

On the other hand, the *standard deviation* of the dataset is also quite low which indicates that the values are scattered around the mean. Hence, a clear idea of the dataset was gained with the help of descriptive analysis on the topic.

Table 1. Descriptive Analysis

| FinTech and BCA Impact on Sustainable Entrepreneurship                                  |          |         |         |      |                |
|-----------------------------------------------------------------------------------------|----------|---------|---------|------|----------------|
| Descriptive Statistics                                                                  |          |         |         |      |                |
|                                                                                         | <i>N</i> | Minimum | Maximum | Mean | Std. Deviation |
| Age                                                                                     | 71       | 37      | 73      | 52   | 0.955          |
| Gender                                                                                  | 71       | 0       | 1       | 0.68 | 0.602          |
| A cost-effective blockchain adoption considering FinTech is highly recommended          | 71       | 1       | 5       | 4.20 | 1.283          |
| A cost-effective blockchain adoption considering FinTech enhances customer satisfaction | 71       | 1       | 5       | 4.05 | 1.105          |

|                                                                                                                                              |    |   |   |      |       |
|----------------------------------------------------------------------------------------------------------------------------------------------|----|---|---|------|-------|
| Blockchain adoption should be considered as the most effective trend in sustainable and profitable FinTech solutions for SME                 | 71 | 1 | 5 | 4.12 | 1.197 |
| AI should be considered as the most influential booster in sustainable and profitable FinTech solutions for SME                              | 71 | 1 | 5 | 4.17 | 1.275 |
| For sustainable and profitable FinTech solutions, same-data sharing, smart contracts utilization, and knowledge sharing play a critical role | 71 | 1 | 5 | 4.18 | 1.279 |
| For sustainable and profitable FinTech solutions, transparency, cyber-hacking protection, and fraudulence suspension play a critical role    | 71 | 1 | 5 | 4.14 | 1.201 |
| For sustainable and profitable FinTech solutions, fidelity, integrity, and trust play a critical role                                        | 71 | 1 | 5 | 4.29 | 1.295 |
| Valid <i>N</i> (listwise)                                                                                                                    | 71 |   |   |      |       |

Source: Author compiled (survey's primary data, IBM SPSS processing)

### 3.6. FinTech & BCA impact on sustainable entrepreneurship: frequency analysis

Frequency analysis is defined as a method used to establish the relationship between the magnitudes of extreme meteorological variables, such as precipitation, and their frequency of occurrence through the application of probability distributions.

The questions that were asked by the participants in the survey have been analyzed in this section using the frequency analysis method. Particularly, the analysis involves presenting the primary data and interpreting them to gather the required insights (regarded as sustainable entrepreneurship “statements”).

#### 3.6.1. Start-Ups & sustainable entrepreneurship: “a cost-effective blockchain adoption considering fintech is highly recommended”

Depending on the primarily collected data, the graphical interpretation has highlighted that most of the participants in the survey strongly agreed that the cost-effective approach of FinTech solutions is highly recommended for start-ups. More than 38% of participants strongly agreed with the statement as shown in Figure 4.

**Cost-Effective Blockchain Adoption Considering FinTech is Highly Recommended for Start-Ups**

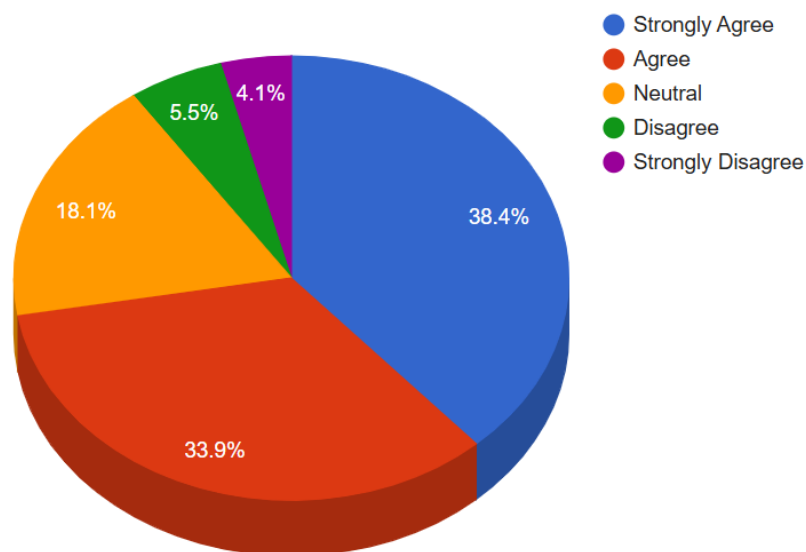


*Fig. 4. Start-Ups: Cost-effective blockchain adoption considering FinTech is highly recommended. Source: Author compiled (survey's primary data, IBM SPSS processing)*

### 3.6.2. Customer satisfaction & sustainable entrepreneurship: “a cost-effective blockchain adoption considering fintech enhances customer satisfaction”

Figure 5 shows that 39.8% of participants agreed that customer satisfaction can be enhanced with the implication of blockchain adoption solutions in corporate sustainable entrepreneurship (FinTech business operations), whereas 32.4% of respondents strongly agreed with the concept.

**Customer Satisfaction & Sustainable Entrepreneurship: A cost-effective blockchain adoption considering FinTech enhances customer satisfaction**

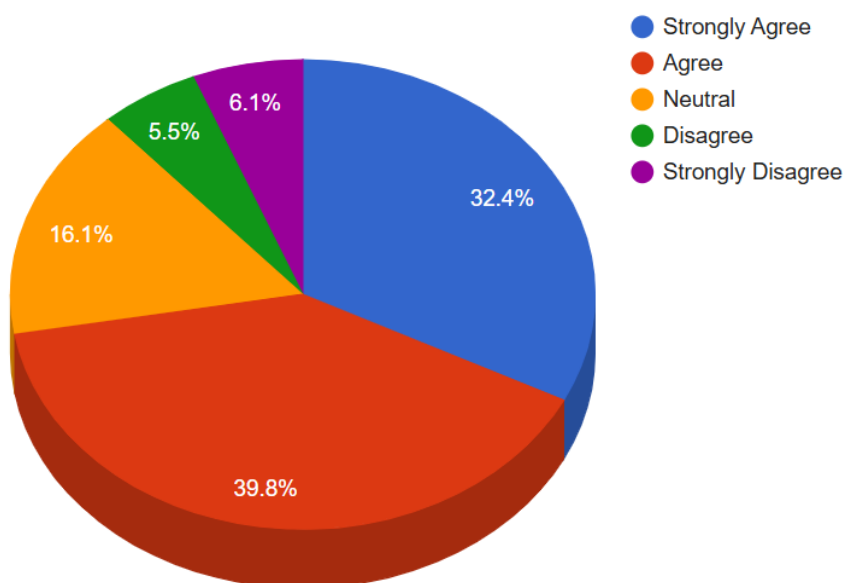


*Fig. 5. Customer Satisfaction & Sustainable Entrepreneurship: A cost-effective blockchain adoption considering FinTech enhances customer satisfaction. Source: Author compiled (survey's primary data, IBM SPSS processing)*

### 3.6.3. Corporate transaction errors & sustainable entrepreneurship: “blockchain adoption should be considered as the most effective trend in sustainable and profitable fintech solutions for SME”

Small and Medium Enterprises (SMEs) play a major role in most economies, particularly in developing countries. For recording and identifying corporate transaction errors, Figure 6 shows blockchain technology is the most effective trend of Fintech financial solutions and that has been agreed by 35.7% of participants of the online survey conducted by the researcher to collect the primary data. Even more, 36.4% of participants strongly agreed with the statement.

**Corporate Transaction Errors & Sustainable Entrepreneurship:**  
**“Blockchain adoption should be considered as the most effective trend in sustainable and profitable FinTech solutions for SME”**

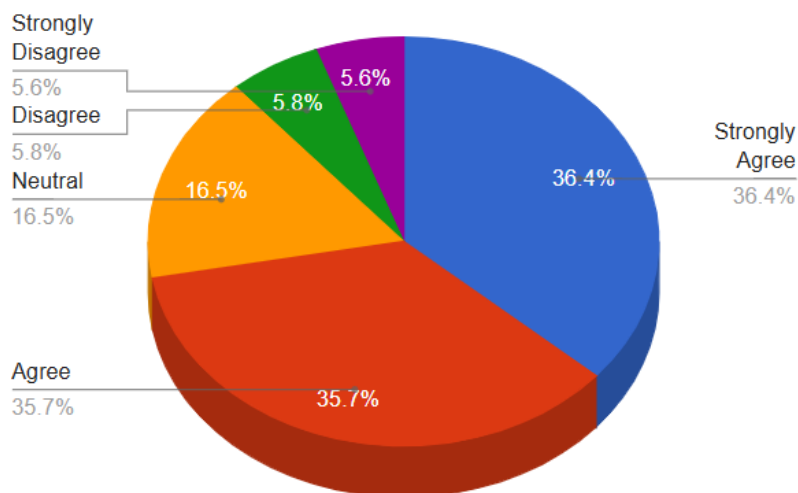


*Fig. 6. Corporate Transaction Errors & Sustainable Entrepreneurship: “Blockchain adoption should be considered as the most effective trend in sustainable and profitable FinTech solutions for SME”. Source: Author compiled (survey’s primary data, IBM SPSS processing)*

### 3.6.4. Artificial Intelligence & sustainable entrepreneurship: “ai should be considered as the most influential booster in sustainable and profitable fintech solutions for SME”

Among the participants, 37.3% strongly agreed that Fintech profitability is to some extent dependent on the AI technological interpretation as shown in Figure 7. Similarly, 36.3% of participants agreed with the statement that ensuring AI is enacted as a booster to increase Fintech profitability in sustainable entrepreneurship businesses.

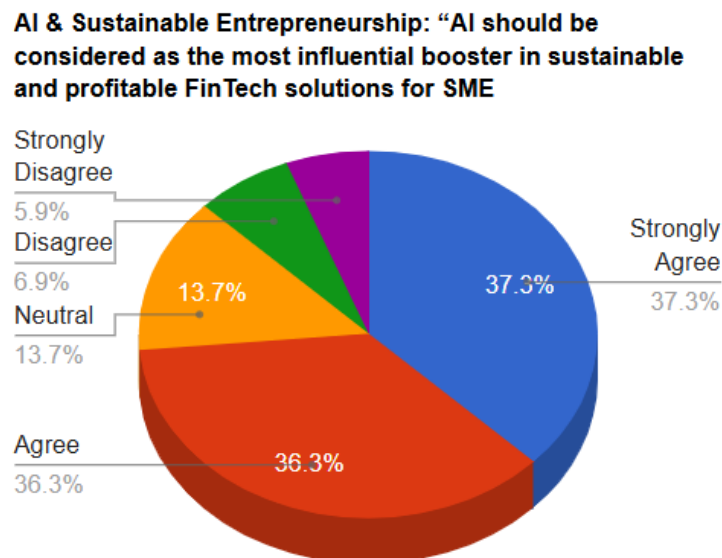


*Fig. 7. Artificial Intelligence & Sustainable Entrepreneurship: “AI should be considered as the most influential booster in sustainable and profitable FinTech solutions for SME”.*  
*Source: Author compiled (survey’s primary data, IBM SPSS processing)*

### 3.6.5. Same-data sharing, smart contracts utilization, knowledge sharing & sustainable entrepreneurship: “for sustainable and profitable fintech solutions, same-data sharing, smart contracts utilization, and knowledge sharing play a critical role”

Same-data sharing, smart contracts utilization, and knowledge Sharing, as emerging blockchain adoption functionalities in entrepreneurship business enhance the probability of innovation and can add an extra competitive advantage for entrepreneurial institutions to participate in the global business market. This sustainable entrepreneurship statement is strongly agreed upon by 37.5% of participants in the online survey as depicted in Figure 8.

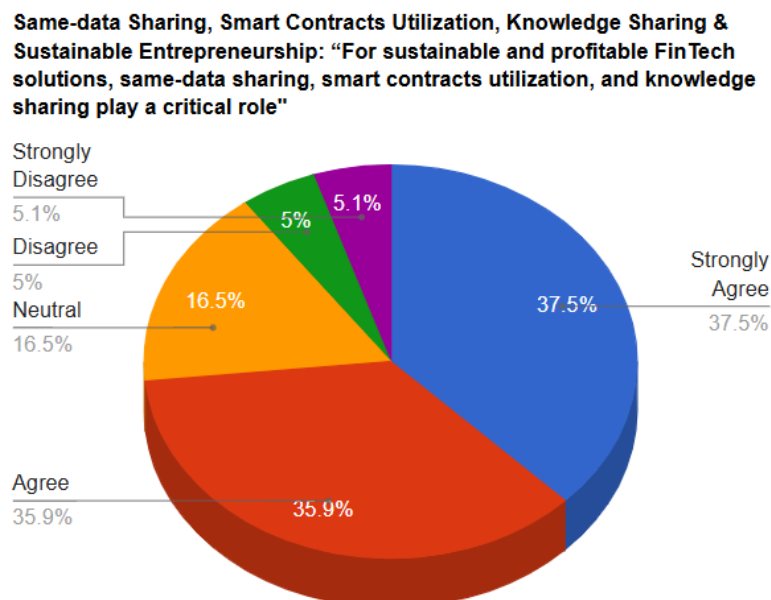


*Fig. 8. Same-data Sharing, Smart Contracts Utilization, Knowledge Sharing & Sustainable Entrepreneurship: “For sustainable and profitable FinTech solutions, same-data sharing, smart contracts utilization, and knowledge sharing play a critical role”.*  
*Source: Author compiled (survey’s primary data, IBM SPSS processing)*

### 3.6.6. Transparency, cyber-hacking protection, fraudulence suspension & sustainable entrepreneurship: “for sustainable and profitable fintech solutions, transparency, cyber-hacking protection, and fraudulence suspension play a critical role”

Transparency, cyber-hacking protection, and fraudulence suspension, as emerging blockchain adoption functionalities in entrepreneurship business enhance the probability of innovation and can add an extra competitive advantage for entrepreneurial institutions to participate in the global business market. This sustainable entrepreneurship statement is strongly agreed upon by 37.1% of participants in the online survey as depicted in Figure 9.

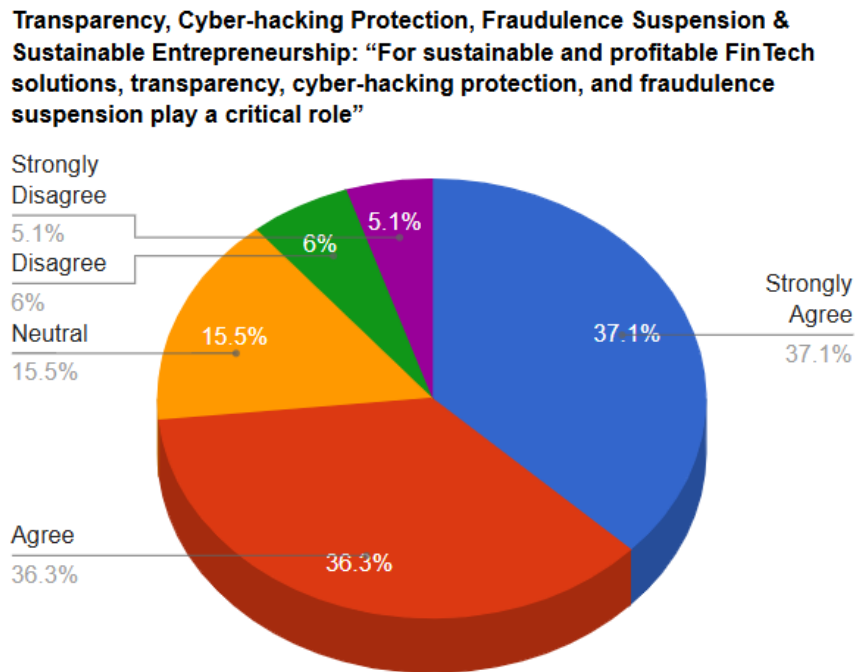


Fig. 9. Transparency, Cyber-hacking Protection, Fraudulence Suspension & Sustainable Entrepreneurship: “For sustainable and profitable FinTech solutions, transparency, cyber-hacking protection, and fraudulence suspension play a critical role”.

Source: Author compiled (survey’s primary data, IBM SPSS processing)

### 3.6.7. Fidelity, integrity, trust & sustainable entrepreneurship: “for sustainable and profitable fintech solutions, fidelity, integrity, and trust play a critical role”

Fidelity, integrity, and trust, as emerging blockchain adoption functionalities in entrepreneurship business enhance the probability of innovation and can add an extra competitive advantage for entrepreneurial institutions to participate in the global business market. This sustainable entrepreneurship statement is strongly agreed upon by 39.4 % of participants in the online survey as shown in Figure 10.

**Fidelity, Integrity, Trust & Sustainable Entrepreneurship: “For sustainable and profitable FinTech solutions, fidelity, integrity, and trust play a critical role”**

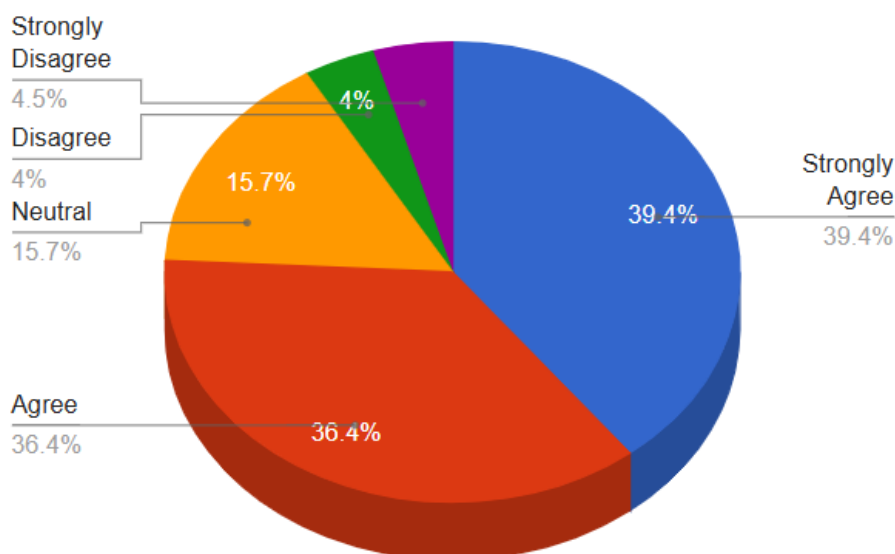


*Fig. 10. Fidelity, Integrity, Trust & Sustainable Entrepreneurship: “For sustainable and profitable FinTech solutions, fidelity, integrity, and trust play a critical role”.*

*Source: Author compiled (survey’s primary data, IBM SPSS processing)*

#### 4. Findings

The final findings of the study highlighted that FinTech solutions have a positive impact on entrepreneurship businesses when blockchain technology adoption is mediating. Blockchain technology and AI can be considered the most influential booster for the increasing profit of businesses. The potential risk identification of Fintech technology also plays a vital role in entrepreneurship businesses. Innovation criterion is also prioritized by FinTech/BCA financial solutions that highlighted the investment opportunities for start-ups. The cost-effective digital transaction approach of Fintech solutions helps in enhancing customer satisfaction and reflects on the profitability rate of entrepreneurship businesses.

The secondary data of the study have been briefly discussed thematically with seven “statements”. Particularly, the analysis involves presenting the primary data and interpreting them to gather the required insights (regarded as sustainable entrepreneurship “statements”). The future perspectives of FinTech solutions also have been interpreted in this study to evaluate the economic stability of the businesses in future. The advantages of Fintech technology and its impacts on small businesses including entrepreneurship businesses also have been considered in this study as final findings. Security enhancement is one of the most effective advantages of FinTech technology considering the transparent transactions and keeping records of the transaction in digital ledgers (i.e., DLT/distributed ledger technology with a Blockchain database) that ensure great financial functionalities.

Fig. 11 shows the adopted conceptual framework of the current study with four *independent* variables (Big analytical data as primitive data, FinTech financial solutions, Blockchain adoption functionalities, and AI add-in solutions) and one dependent variable (Sustainable Entrepreneurship) variable (Gupta and Jindal, 2024; Kathuria et al., 2024).

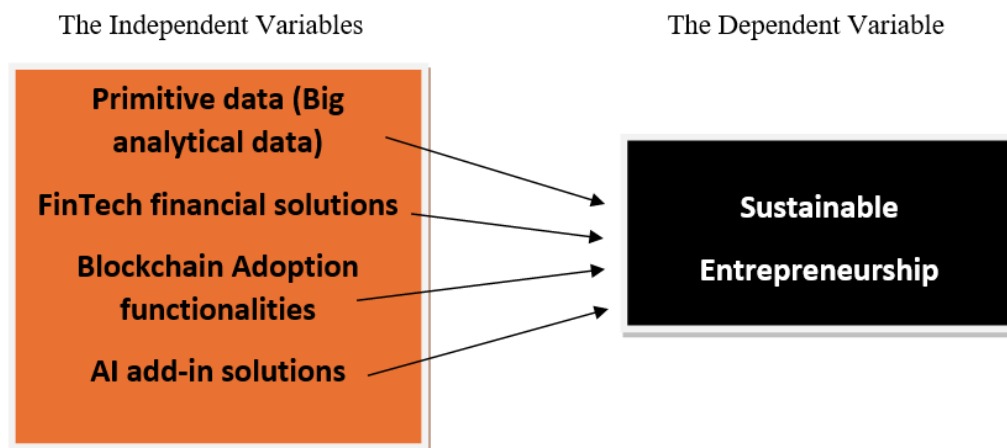


Fig. 11. The proposed conceptual framework. Source: Author-developed

## 5. Conclusions

The proposed study has helped us to understand and evaluate the impact of the Fintech/Blockchain adoption technology on sustainable entrepreneurship businesses. Particularly, study's conceptual design helps to derive insights into financial performance with seven sustainable entrepreneurship statements.

Descriptive analysis utilizes a better sense of the survey-collected primitive data to better understand their "characteristics" and "features" (Table 1). Additionally, frequency analysis was used to establish the relationship between the proposed four independent variables and the dependent one (Fig. 11). The questions that were asked to the survey participants have been analyzed and the analysis involves presenting the primary data and interpreting them to gather the required insights, regarded as sustainable entrepreneurship "statements" (Figs. 4-10).

Finally, the graphical interpretation of primary data has highlighted the impact of blockchain technology functionalities (transparency, same-data sharing, knowledge sharing, smart-contract utilization, cyber-hacking protection, fraudulence suspension, fidelity, integrity, and trust) on sustainable entrepreneurship businesses considering financial Fintech solutions.

As the paper's implication could be regarded the advice to start-ups and SME to consider a sustainable and profitable business performance outlook with FinTech financial solutions adopting blockchain technology.

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