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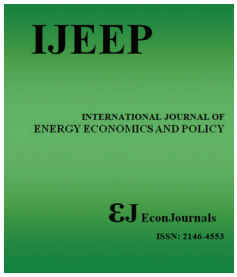

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Eco-Smart Economics: Revolutionizing Jordan's Logistics with Sustainable Drone Technology

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ABSTRACT

This study explores the implications of sustainable drone technology on the development of Jordan's logistics sector through the eco-smart economics (ESE) lens. Based on in-depth qualitative data drawn from 42 semi-structured interviews conducted in Jordan, the study evaluates drones' influences on environmental, operational, and economic processes, finding that drone technology has the potential to substantially improve delivery timeframes, diminish carbon emissions, and contribute to the sustainable development agenda. However, the study has outlined several limitations, such as regulatory, technical, and public concerns, especially related to privacy and security. In this regard, for Jordan to benefit from drones in the logistics sector, policy, technological, and partnership advancements are required. Such changes would ensure that Jordan develops a sustainable, rapid, and efficient logistics sector to strengthen its economy.

Keywords: Sustainable Drone Technology, Jordan's logistics, Eco-smart Economics, Operational Efficiency, Environmental Sustainability
JEL Classifications: R41, Q56, O33

1. INTRODUCTION

Integrating advanced technologies into supply chains can result in cost reductions, optimized logistics, enhanced accuracy, and increased trust among stakeholders, thereby fostering competitive advantage and elevating customer satisfaction (Younis et al., 2024). One such critical technology is drone technology, also known as unmanned aerial vehicle (UAV) or unmanned aircraft system (UAS) technology. This term encompasses the development, design, and deployment of remotely controlled or autonomous flying machines. These drones exhibit considerable variation in size, shape, and function, ranging from small consumer quadcopters to large military aircraft. The role of drones in logistics is critical, as they have the potential to reduce energy and gas emissions significantly, and thus promote a more sustainable systemic paradigm. The notable recent work of Bányai (2022) reported on ways in which the use of drones in the logistics industry offers new and effective ways to address typical challenges, such as high transportation prices and environmental damages, among others. Drones are responsible for driving efficiency, affordability, and safety in logistics operations. For instance, in terms of piloting and scheduling, as discussed by Murray and Chu (2015), they reduce both operational costs and environmental footprint. Albeit such advantages are intriguing, the implementation of drone logistics to their full potential is full of challenges, including regulatory, privacy, environmental, technical, and economic barriers, which need to be overcome to explore the maximum potential of drones in the logistics sector (Sah et al., 2021).

Despite the mentioned disadvantages, drones are envisioned to bring fundamental and substantive improvements to operations, mainly in relation to smart warehouse management, where they enable the simplification of inventory management, intra-logistics, inspections, and surveillance. Other technological innovations and germane government regulations can galvanize the latent efficacy of drone systems. Rapid and effective technological innovations

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are essential to continually reduce the carbon footprint of logistics operations, especially in relation to delivery times (Goodchild and Toy, 2017; Park et al., 2018). Related regulations can create an environment that enhances the safety and sustainability of urban logistics (Raj and Sah, 2019; Tadić et al., 2021). The eco-smart economics (ESE) paradigm, based on responsibility and efficiency in relation to sustainable economic development, transcends operational benefits due to sustainability and pinpoints sustainability and long-term oriented investment in renewable energies and overall efficiency improvements (Sandri et al., 2020).

Drone usage in Jordan's logistics system can open a new chapter of operational efficiency while at the same time minimizing adverse environmental outcomes of transportation and storage. This study explores the sustainable integration of drone technology into the logistics industry in Jordan from this perspective, presenting novel drone technology advancements in learning, spatial visualization, and logistic planning by use. It further explores the socioeconomic-environmental aspects of drones in Jordan's logistics matrix, supporting a persuasive structure identifying merging ESE with technology innovation as a basis for an efficient and sustainable logistics matrix. This forms the core purpose of this analysis, contributing original insights into contemporary developments in drone technology and application in logistics, and exploring what the future presents in terms of opportunities and challenges.

The main aim of this study is to gain an understanding of the logistics structure in Jordan by undertaking an exploratory examination to test whether drone technology could have a place in this sector at some point, given the complex environment. The specific objectives that this aim entails include an analysis of the existing structures and a conclusion on the prospect of integrating drone technology with a view to identifying ways to improve efficiency. In addition to this, it also seeks to identify the possible remote drone applications that are feasible in a unique way and some existing solutions that could be rolled over to the Jordanian environment. The study also investigates the barriers and benefits of implementing practical expression of drone invention in the logistics sector of Jordan, encompassing the economic, technical, and regulatory dimensions, to present a panoramic overview of the topic. Furthermore, the study assesses the role and activity of the government and its frameworks and influence on the implementation of the own-inventing and the external support to it. At the same time, the study considered emerging and potential drone impacts on the ESE of Jordan, and its potential to support it in the future with short- and long-term usage outcomes.

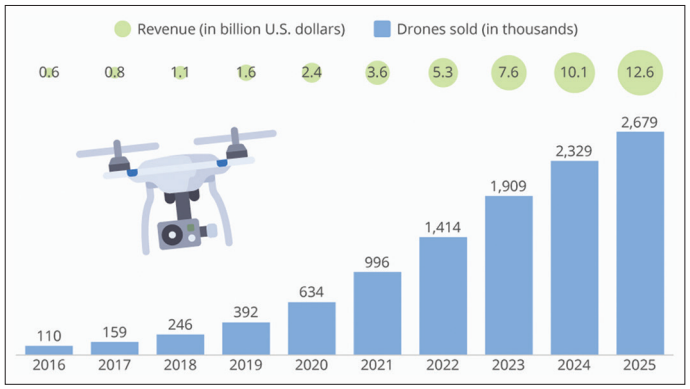
2. LITERATURE REVIEW

2.1. Theoretical Background and Conceptual Framework

2.1.1. Drone technology theory

The "Global Drone Market Report 2023-2030" by Drone Industry Insights (2023) predicts over 7% compound annual growth rate (CAGR) drone market growth, to reach USD 54.6 million by 2030, based on data compiled from 181 countries. The commercial drone sector is poised for even more rapid growth, with projections indicating a robust 7.7% CAGR. In contrast, the recreational

Figure 1: Predicted worldwide market growth for commercial drones (Statista, 2024a)



counterpart is expected to exhibit a modest - 0.3% CAGR. The commercial drone market is led by Asia, largely due to strong consumer demand in China and Japan, but the Middle East and North Africa region is poised for rapid development. Figure 1 illustrates the predicted worldwide market growth for commercial drones until 2025.

As regulations become more lenient and drone technology advances, the commercial use of drones is set to rise. Although current logistics drone regulations are strict, they are expected to be relaxed to accommodate drone deliveries and other applications. Drone technology is gaining momentum in the logistics industry, offering significant advantages for customers and companies. The use of drones in logistics is expected to increase in the coming years, as shown in Figure 2. By 2030, the logistics drone market is forecast to become the largest segment, followed by the enterprise and defence sectors (Lattice, 2023). Adopting drone technology in the logistics sector requires a comprehensive approach that includes enhancing operational efficiency, securing technological and regulatory backing, and addressing prevalent challenges. This study, building upon existing research, offers a detailed framework for understanding and advancing the integration of drones in logistics operations. Figure 3 illustrates the industries where drones are expected to exhibit the most rapid and dramatic adoption in the near future.

2.1.2. Conceptual framework

The comprehensive review of the existing literature led to the framework proposed in Figure 4 for Jordanian logistics to become planet-friendly through sustainable drone technology based on the ESE tenets. The framework outlines the influence of ESE on the effect of drones in the economy on operations, sustainability, regulations, and technological factors, based on the case of Jordan. In the context of ESE, operations can be enhanced by drones enabling quicker delivery and reducing delivery costs. In terms of sustainable development, drones can contribute to lower carbon emissions and enhanced renewable energy. Additionally, drones can support regulations through policy frameworks and safety standards. Finally, drones can provide technological advancements in terms of innovation and infrastructure. This study elaborates on a conceptual framework to extend beyond various existing studies on drone technology adoption within the logistics sector, focusing on several critical aspects: enhancing operational efficiency and

Figure 2: Estimated value of global drone market applications in different industrial sectors (Lattice, 2023)

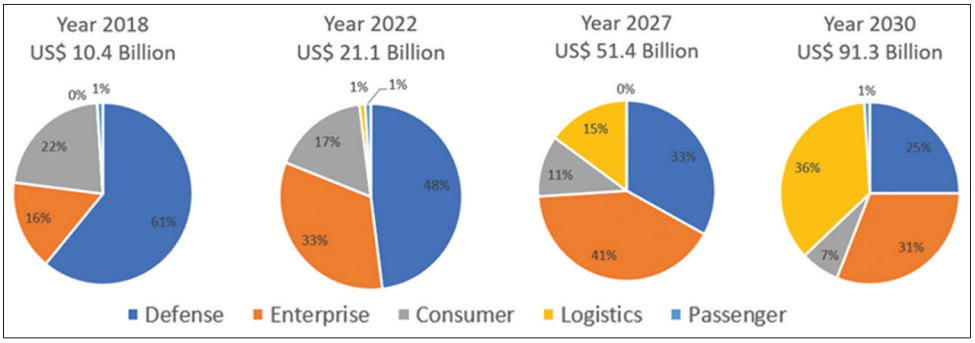
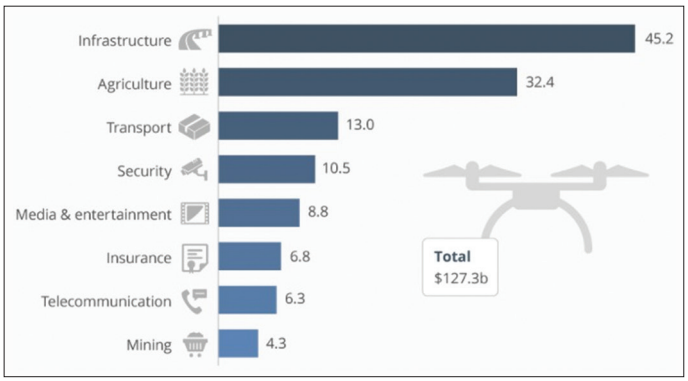


Figure 3: Value of drone-powered solutions for industries (billion USD) (Statista, 2024c)



sustainable development, securing technological and regulatory support, and addressing prevalent challenges (e.g., regulatory constraints and privacy/security concerns).

2.1.3. Operational efficiency

Operational efficiency in drone-based logistics is crucial, as drones offer innovative solutions to both first-mile and last-mile delivery challenges. First-mile delivery refers to the initial stage of the logistics process, where goods are transported from the manufacturer or supplier to a central warehouse or distribution center. Last-mile delivery refers to the final stage, where goods are transported from a distribution center to the end consumer's location. Drones can accelerate delivery processes by a factor of four and reduce costs by 50%, as illustrated in Figure 5, thereby positively impacting energy efficiency and the environment. Bányai (2022) discussed the integration of drone operations with trucks, enhancing energy efficiency and environmental sustainability. In addition, Murray and Chu (2015) delved into optimizing drone-assisted parcel delivery, illustrating the efficiency gains through strategic routing.

2.1.3.1. Faster deliveries

As the logistics industry in Jordan matures, sustainable drone technology is slowly rising to become a transformative force, poised to spur deliveries while ensuring environmental sustainability. The sequence diagram displayed in Figure 6 shows how various players interact with the drone technology that has been developed and the environment it has been developed into, in consideration of the logistics environment. The customer is the point of origin for the process sequence, placing an online order via a logistics company platform. After receiving this order, the logistics company evaluates the specific order characteristics in order to determine the best method of delivery. The logistics company, if the parameters like distance and size of the package are fit for drone delivery, sends a request to deploy a drone for the task. Compared to traditional methods, this eventually allows the reduction of the delivery lead time and the simultaneous minimization of carbon emissions produced from optimal delivery paths and space requirements for vehicle-based carriage of goods (Goodchild and Toy, 2017; Park et al., 2018; Bwaliez and Abushaikha, 2019; Chiang et al., 2019).

Next, an operator sends out a drone from the nearest distribution center to collect the package. The drone flies to the indicated pickup point, picks up the package there, and then the drone operator plots the cheapest route to the point of delivery, taking into consideration various parameters such as the obvious issue of distance, the weather, airspace restrictions, and high buildings or natural structures (if applicable). Such operations have potential high efficiency, which could considerably reduce the energy consumption and carbon emissions of a drone-based delivery service integrated into a truck-based system for first-mile and last-mile deliveries (Bányai, 2022). After defining the route, the drone takes off and flies autonomously along the plotted route up to the location of delivery. Upon arrival at the customer's location, the drone alerts the customer and delivers the package right into their hands. On successful confirmation of the delivery, the drone returns to the nearest distribution center or charging station and can have its battery recharged before going out for another delivery mission. Besides accelerating the delivery process, this particular logistics chain part made possible by drones adds to sustainability through reducing the logistical footprint, hence reducing road congestion, which has broader macroeconomic and environmental impacts and localized urban planning benefits (Li et al., 2022).

2.1.3.2. Reduced costs

Drones have the potential to revolutionize mid-mile deliveries in several ways (Chiang et al., 2019). Mid-mile deliveries refer to the intermediate stage of the logistics process, where goods are transported from a central warehouse or distribution center to regional hubs or local distribution centers. This stage bridges the gap between the first-mile and last-mile deliveries, facilitating the efficient movement of goods through the supply chain. Unlike entering traffic-choked streets, drones fly through the airspace freely. As a result, packages take much less time to

Figure 4: Conceptual framework

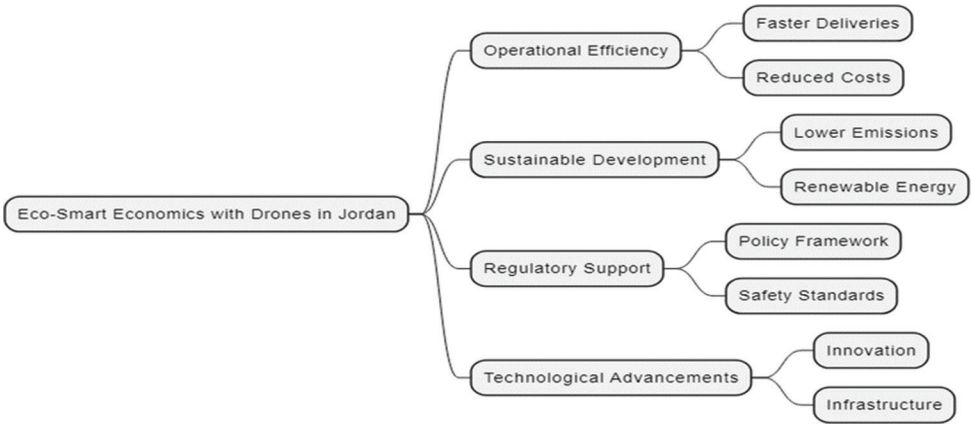


Figure 5: Drones' first-mile and last-mile delivery (Teamlease, 2024)

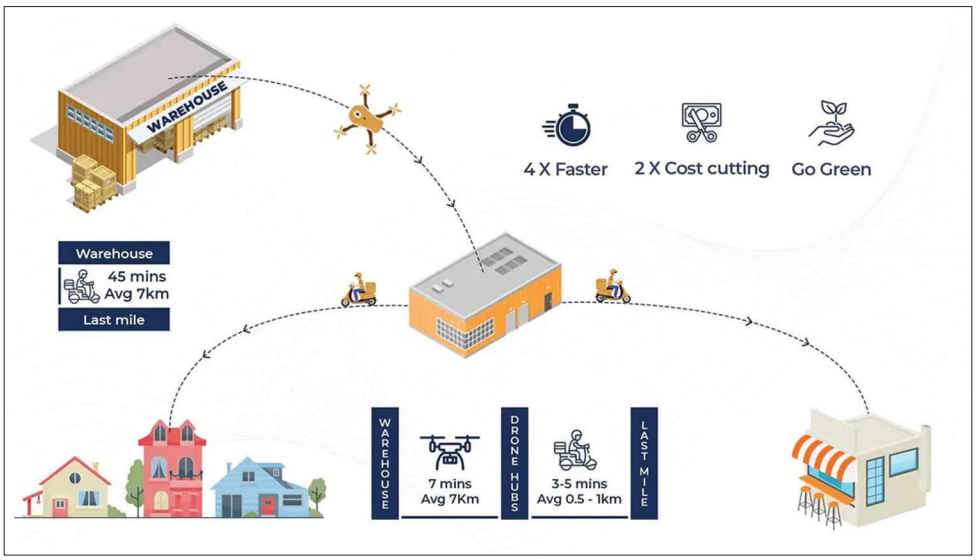
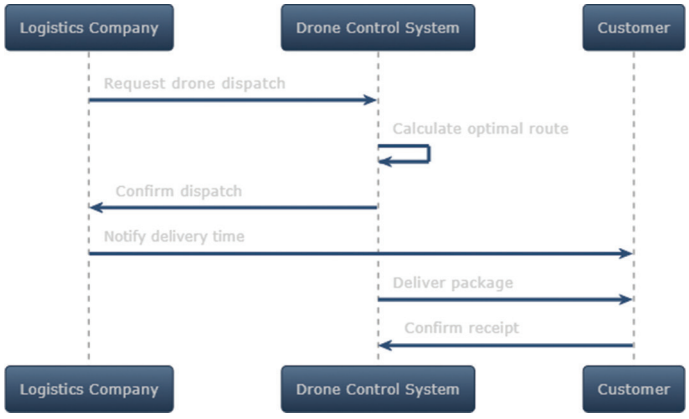


Figure 6: Sequence diagram illustrating interactions involving sustainable drone technology in Jordan's logistics sector



reach their destinations than traditional delivery vehicles. This can significantly shorten mid-mile delivery times, as many are too long to use the less expensive last-mile models. By reducing the necessity of human labor, drones are generally not that expensive to operate due to the automation involved (Chiang et al., 2019). They also do not require expensive and extensive infrastructure, such as roads and robust transportation vehicles, to convey and conduct themselves safely (e.g., posing less risk to conventional road users). Furthermore, drones can reach extremely difficult places without adequate human utilization terms that terrestrial standard ones could not have accessed (Park et al., 2018). This utility is especially valuable in areas with weak or non-existent infrastructure or following natural or human-made calamities. Furthermore, drones might allow a reduction in carbon emissions and a concomitant environmental footprint, especially if their power comes from renewable sources (Stolaroff et al., 2018).

Drones have been designed to deliver packages directly to the users' preferred delivery places, such as backyards or balconies, improving convenience and usability. They are equipped with collision-avoidance systems and compartments that protect packages in case of a crash. Additionally, drones offering real-time package monitoring ensure that packages reach their destinations without theft or loss during transit (Goodchild and Toy, 2017). Moreover, drones are capable of adjusting speed and arrival time in response to the consumer's requirements, which is highly beneficial for shortening the length of delivery or keeping the product relevant as well as ensuring customer convenience and reduced waste. Nonetheless, the use of drones in the delivery sphere has significant barriers, including legal and airspace

Figure 7: UN sustainable development goals (UN, 2015)

restrictions, real and perceived drone accidents, and antipathy among large proportions of the general public (Nentwich and Horváth, 2018). However, through technological developments and broader regulation adoption, drones are expected to become influential in the middle-mile delivery business.

2.1.4. Sustainable development

2.1.4.1. ESE

ESE is a new method that focuses on the relationship between sustainable development and economic efficiency, environmental protection, and the reduction of carbon emissions. It is used within the framework of the United Nations' (UN, 2015) "2030 Agenda for Sustainable Development Goals (SDGs)", as shown in Figure 7. ESE is based on the principles of sustainable development, economic effectiveness, environmental protection, and low carbon emissions. Reviewing related studies in the literature reveals that sustainable economic development and eco-efficiency are crucial for carbon regulation, and that eco-efficient cities require comprehensive approaches (Sandri et al., 2020). Scholars emphasize that all of these components are not only necessary but also urgent measures in order to ensure a promising and sustainable future (Sandri et al., 2020; Zhang et al., 2021a; Sharabati et al., 2022).

At the heart of ESE lies the principle of sustainable economic growth and eco-efficiency. According to Lupan and Cozorici (2015), governmental and corporate initiatives in this area consensually insist on the need for public-private equilibrium in environmental and economic development issues, with resource efficiency in production to minimize negative environmental blowback. Economic meaningfulness and environmental interest are the two animating principles of ESE, which posits compliance with these principles as a necessary component of the logic of the sustainable economy model, thereby promoting economic growth (and socio-economic development) alongside eco-efficiency.

The concept of eco-efficient urban development is another pivotal aspect of ESE. De Jong et al. (2015) shed light on the analysis of sustainable, smart, resilient, low-carbon, and eco-knowledge cities. Their study advocated for an integrated urbanization approach that aligns economic, environmental, and social goals. This integration is crucial for developing urban areas that are not only economically viable but also environmentally sustainable and socially equitable, thereby embodying the essence of ESE. Finally, eco-efficient urban development is another substantial aspect of ESE. According to De Jong et al. (2015), sustainable, smart, resilient, low-carbon, eco-knowledge cities should be analyzed. The authors promoted an integrated approach to urbanization in which the economic, environmental, and social plans are balanced. Such coordination will help to create urban areas that are economically sound, as well as environmentally friendly and socially just, which are the core tenets of ESE.

2.1.4.2. Lower emissions

Furthering the discourse on eco-efficiency, Zhang et al. (2021a) explored the changing carbon emission matrices. The issue was researched and formulated with high-quality economic growth. Based on their conclusion, it is necessary to consider eco-efficiency as a necessary assumption for generating economic paradigms used for determining the use of carbon human resources. This means that long-term sustainability, economic development, and eco-efficiency should be complementary through a range of instrumental policies in carbon management.

2.1.4.3. Renewable energy

Renewable energy is one of the necessary aspects of sustainable economic growth in specific relation to ESE. Previous studies demonstrated that solar and wind energy is a promising source that helps reduce the level of carbon emissions while also securing energy (UN, 2015; Zhang et al., 2021b). Other studies also outlined the importance of technological advancements in energy storage and smart grids, since they make renewable energy more efficient and feasible within national systems, and battery recharging issues are the bane of AEVs and other emerging technologies (Stolaroff et al., 2018; Alotaibi et al., 2020). In Jordan, renewable energy initiatives are part of eco-smart strategies aimed at minimizing the negative environmental impact of urban and industrial activities (Alotaibi et al., 2020; Sandri et al., 2020). Financial investments

in renewable infrastructure in Jordan indicate the target of sustainable development. The efforts are especially crucial for Jordan because its energy import is very expensive, yet it has a perspective of boosting its economy and ensuring environmental sustainability (Ibrahim and Ali, 2019; Abu-Rumman et al., 2020; Sandri et al., 2020).

2.1.5. Regulatory support

The regulatory environment typically poses challenges to drone adoption and use. Due to legitimate reasons for actually safeguarding the public (i.e., human life, rights, and property), and the legacy of traditional airspace regulations developed with manned aircraft in mind (which do not necessarily apply to UAVs), drones face inhibitions from regulatory restrictions at the national and international level of operation. Sah et al. (2021) examined barriers to drone logistics appliances and identified legislation and the related issue of privacy as the main impediments. In a recent work by Nurgaliev et al. (2023), the authors discussed drones and unmanned vehicles as logistics appliances, focusing on the legal and regulatory barriers and measures for drones and unmanned vehicles to be incorporated into the delivery process, and they noted the ongoing need for substantive progress in these aspects worldwide.

2.1.5.1. Policy framework

For drones to be incorporated in the logistics supply chain, strict policies must be enacted to cater for technical and regulatory aspects, facilitating the responsible use of developing technology and the safeguarding of public safety and privacy (Raj and Sah, 2019; Sah et al., 2021). It is possible to find support for this consensus in many studies, and the question of adaptive and agile policy frameworks is also supported with insights that the pace of technological and market change would require such a response (e.g., Nurgaliev et al., 2023). Furthermore, productive policy must stimulate experimentation and pilot projects, that are important for solving the careful hurdles inside the domain of drone logistics implementation. Lastly, the government should engage with industrial, professional, and research organizations on the development of policy and regulatory processes that support the usage of drones in the environment (Ali et al., 2023a; Eskandaripour and Boldsaikhan, 2023). Additionally, thanks to the cooperation, companies may come up with protocols and blueprints of collaboration that will secure the population and boost their trust concerning drones.

2.1.5.2. Safety standards

There should also be a safety standard for drones to guarantee the safety of the general population, in terms of their bodies and property in addition to their privacy. Sah et al. (2021) implied that safety regulations should consider all the potential dangers of drone use, namely the risk of accidents or the risk of data breach. Thus, comprehensive safety guidance concerning the training of pilots, regulations about drone maintenance, and safety of communication could eliminate all the risks (Al-Tahat and Bwaliez, 2015; Floreano and Wood, 2015; Dawodu, 2020; Ta'Amnha et al., 2023). The applications of geofencing or connecting drones with a traffic control system could also bolster the safety of the manned systems. By explicitly establishing safety guidelines, the public will be able to trust and accept drone potential while preserving their right to privacy. Smith (2020) and Yu (2023) argued that a public safety campaign would help combat that fear, allowing drones to be used in major-looking urban environments and seemingly random rural ones.

2.1.6. Technological advancements

The efficient integration of drones in logistics necessitates vital technological enabling and regulatory backing. For example, Ali et al. (2023b) investigated drones' implementation into smart warehouse management, discovering what technological advancements facilitated logistics activities. Similarly, Raj and Sah (2019) found the technological equivalent of the drones' capacities. Nevertheless, they also acknowledged the need for regulatory assistance as a fundamental prerequisite.

2.1.6.1. Innovation

The advancement of drone technology is revolutionizing the area of logistics, as drones are now being used with a variety of new functionalities (Li et al., 2022). These developments, together with the ability to deploy drones almost anywhere, including both crowded cities and rural enclaves, due to the powered navigation, improved payload, and battery life, are likely to contribute significantly to their use in logistics and beyond (Eskandaripour and Boldsaikhan, 2023). The combination of Internet of Things devices with drones enhances data collection quality and processing for making better decisions about logistics operations management. This is especially important for the development of smart logistics platforms that can bidirectionally and asynchronously change and vary, depending on particular (and dynamic) customer requirements (Ali et al., 2023a; Raj and Sah, 2019).

2.1.6.2. Infrastructure

Apart from the software, the drone logistics service would also require infrastructure. Essentially, the needed infrastructure would comprise a charging station and maintenance station network, security sensors and cameras to safeguard the air corridor, and lanes for directing the movement of the drones (Nurgaliev et al., 2023). Additionally, drones have to be combined with other transport types for them to be used as multimodal, integrated distribution systems. Additionally, many safe drones meet the requirement for assured takeoff and landing for use in specially designated areas planned to avoid downtown geographical separation. Drone systems require ample investment in telecommunications infrastructure, needing entire data systems to run it. To keep the flight system quick and secure for cost and other factors, real-time transmission and power are required. This complexity can be released by the increasing speed of cell technology and spectrum executed by 5G systems (Dawodu, 2020; Tadić et al., 2021).

2.2. Drone Technology in Jordan's Logistics

This study looks into the incorporation of environmental-friendly drone technology into the Jordanian logistics industry and focuses on the current status, global experiences, difficulties, possibilities, and the government/policy roles in promoting it.

2.2.1. Current state of Jordan's logistics

2.2.1.1. Sustainable and eco-smart logistics

Jordan may be considered as actively moving towards environmentally sustainable logistics. However, while it faces challenges (e.g., dependence on imported energy), the country is on the way to minimal environmental impacts. This path is essential for the country to become sustainable from both environmental and economic perspectives (Ibrahim and Ali, 2019; Hajar et al., 2020; Sandri et al., 2020; Smith, 2020). The literature presents central findings that provide the basis and make clear the present status and likely prospects of sustainable and eco-smart logistics in Jordan (e.g., Smith, 2020; Alnsour et al., 2023).

Firstly, there is a major mismatch between the existing status of logistical activities in Jordan's cities and the goals of sustainability. Alnsour et al. (2023) observed that there is a vital need to improve regulatory measures, and the performance of human resources, systems of information, and coordination of stakeholders, among other aspects to promote sustainability in the industry.

Secondly, sustainable urban freight logistics is of utmost importance for building smart cities. Ibrahim and Ali (2019) as well as Lv et al. (2020) addressed the need for a new conceptual framework that brings together smart logistics and sustainable development. The new approach to sustainable urban freight logistics must rely on interdisciplinary collaboration and disruptive innovations, showing the importance not just of advanced logistics but advanced logistics committed to SDGs.

Thirdly, the transportation sector, especially in Jordan's major tourism cities, requires significant changes to support sustainable tourism and economic growth. According to Alkheder (2016), comprehensive planning and infrastructure enhancements are essential to accommodate and promote sustainable tourism practices, which in turn can contribute to the country's overall economic development.

Finally, it is possible to note Jordan's struggles in building a sustainable energy sector. High import reliance and the growing volume of domestic consumption make it critical for the country to invest in renewables and energy efficiency (Bwaliez, 2023). As Sandri et al. (2020) argued, these measures are essential for Jordan to develop and become a country with sustainable energy and environment and economic sustainability.

2.2.1.2. Challenges and regulatory environment in Jordan

Jordan's sustainable development policy is articulated through several pillars, including city logistics, renewable energy, sustainable tourism, and construction working around green practices. Each key sector entails specific sustainable development-related challenges and opportunities, and requires comprehensive, leveraging, and integrated approaches to achieving goals. In the city logistics sector, Jordan experiences such challenges as regulatory simplification and improvement, development and implementation of human resource-centric training programs, and activity data availability, but it should be noted that sound impact assessment and stakeholder coordination mechanisms are already in place. Alnsour et al. (2023) observed a wide gap between current initiatives and the results achieved in city logistics, and highlighted changes in regulations, the need for programs to train employees in a more comprehensive way, and the requirement for more information systems and related infrastructure in order to embed sustainability as an operational reality.

Moreover, another critical area in the development of sustainable tourism in Jordan is the need for major improvements in the means of transportation to strengthen economic growth and environmental viability, which has mainly been explored concerning the tourist industry. Alkheder (2016) stated that significant changes in the existing transportation system have to be implemented to support this particular sector, and the integration of renewable energy in the architecture and urban design of Jordan is crucial. For example, Ibrahim and Ali (2019) argued that the project of the greening of the central district of Irbid demonstrates how renewable energy systems can be implemented in the architectural form to create further environmental and economic advantages. Additionally, Jordan faces issues of resource scarcity and dependency on energy imports which also affect the sector's sustainability (Bwaliez, 2023). Thus, Sandri et al. (2020) discussed the investment in renewable energy as well as energy efficiency to alleviate the existing challenges and provide the country with a secure energy future, due to its sensitivity to external factors and the gifted solar resources that the country should exploit to have a diversified energy portfolio.

Concerning green building practices in the construction industry, the concept of sustainable green buildings in Jordan faces economic constraints across its lifecycle, reflecting the need for multiple stakeholder consultation and analysis (Ahram and Zakaria, 2023). Ali and Al Nsairat (2009) detailed efforts including the development of green building assessment tools to benefit the environment and promote social and economic development, underpinning sustainable construction methodologies as contributing to the overall achievement of sustainable development.

Jordan's energy sector is crucial for the country's political and economic stability as well as national security. While it has been faced with several challenges, such as overdependence from imported sources and a critical need for sustainability, it naturally has a powerful capacity. Sandri et al. (2020) highlighted the essential of emphasizing the country's strategic importance in investing in renewable energy and enhancing efficiency since it will help to decrease dependence on supplies from abroad and become more environmentally friendly.

Regulatory and operational enhancements are warranted for city logistics in Jordan. Alnsour et al. (2023) indicated several proposals that sustainable city logistics may be achieved through regulatory change, human resource improvements, information facilities, and improved stakeholder alignment. This is a way to decrease expenses and ensure that sustainable perspectives are implemented in dealing with the inefficiencies of the logistics sector.

According to Ahram and Zakaria (2023), from the above challenges, it is critical for one to manage the respective budgeting

to help fend off increasing labor, material, and energy costs. From an economic perspective, for instance, sustainable construction is deemed cost-effective as it avoids long-term incurred costs. Therefore, fending off high economic costs is necessary in promoting sustainable construction as it is also essential in ensuring the financial sustainability of green architecture. Sustainable waste management is a cornerstone for achieving green growth in Jordan. Hajar et al. (2020) noted that the country's waste management strategy is designed to reduce landfills, increase recycling, and conserve resources. Such a timely frame would be comprehensive in terms of environmental sustainability, considering the grand design of green growth.

The Jordanian logistics sector is on the verge of an opportunity for transformative growth, making a substantial contribution to the process of sustainable development and its goals regarding ESE (Sharabati et al., 2022). Building on the presented issues and needs, a transformed Jordanian logistics sector can emerge. This can happen by focusing on modern and sustainable practices, developing international relations, following global and local marketing trends, and making investments in advanced technology. City logistics is the key to securing stable growth in the sector in Jordan. Research by Alnsour et al. (2023) emphasized that sustainability will not be achievable through city logistics unless the mentioned gaps are fixed. The regulatory framework, human resource output, performance output, information systems, and stakeholder management are the areas needing utmost improvement to foster sustainability and well-being in the urban setting. In other words, good city logistics management is not just about the environment but positively affects the socio-economic well-being of the urban people.

2.2.2. Potential for drone technology application in Jordan

Drones have tremendous potential for a wide range of applications in Jordan, from environmental research and archaeology to agriculture, infrastructure monitoring, and disaster response. They benefit archaeologists working in Jordan's vast and inaccessible terrain by providing high-quality aerial images that can be used to document and analyze sites in great detail (Smith, 2020). In agriculture, using drones for monitoring crops and assessing soil conditions, precision farming, and resource usage optimization are critical for sustainability (Ahirwar et al., 2019). Environmental conservation is another application of drones, including monitoring ecosystems, animals, and wildlife or ensuring environmental regulations. Urban planning is another possible development area in which drones can play a significant role. Moreover, they can maintain and conduct surveillance on the integrity of structures and public works (Floreano and Wood, 2015).

Regulatory frameworks are essential for integrating drone technology in a safe and effective manner. The challenge of balancing security concerns with technological advantages is a pivotal issue that necessitates careful policy making. However, the integration of these technologies requires a coherent regulatory framework that can accommodate both security and technological concerns. Balancing these considerations is quite a task for the government or authority (Dawodu, 2020). Jordan's future in drone technology appears very promising, offering significant advantages in resource management, environmental monitoring, and enhancing efficiency across various projects. This development is in sync with global trends towards increased drone adoption and the evolution of drone regulations (Yu, 2023). Integrating drones into logistics and other sectors can help establish Jordan as a model of sustainability and innovation for the region, and perhaps the world (Bwaliez, 2021).

3. METHODOLOGY

This study was designed with a comprehensive structured methodology to investigate the integration of drone technology into the logistics segment, taking into account the ESE principles for the particular context of Jordan. Thus, the methodology has the scope to extensively explore drone technology testing and its compatibility with logistics constraints in a bid to achieve ESE. The cornerstone of the data collection process in this study is the use of semi-structured interviews. This qualitative method was chosen due to its flexibility and appropriateness for the collection of specific real-life personal experiences, views, and the knowledge of professionals in the field (Myers, 2019; Ta'Amnha et al., 2021). Consequently, semi-structured interviews enabled the researchers to obtain an in-depth understanding of the implementation of drone technology in the sphere of logistics and the development of ESE.

The data were collected from 42 interviewees working in Jordan. The selection of interviewees was purposefully made to include relevant policymakers as well as international organization representatives with prior knowledge and expertise in logistics, sustainable technology, and economic development. Table 1 shows the salient characteristics of the interviewees. The diversity of participants interviewed from the listed professions offers a comprehensive understanding of the various potential benefits and challenges of drone technology in the logistics sector. The interviews were guided, open-ended talks. Table 2 shows the types of questions that the researcher asked during the semi-structured interview process, discussing particular focus areas on sustainable drone technology and ESE, while allowing for the possibility of follow-up emerging issues articulated by expert participants. The interviews, which typically lasted 45-60 minutes, were conducted between November 2023 and March 2024.

4. RESULTS

The salient results of the semi-structured interviews are presented in Table 3, as discussed below. It can be seen that the Jordanian logistics and transportation sector is currently at a pivotal moment in its existence because drones are likely to change the whole paradigm. In pioneering applications certifying the immediate delivery and regular transportation models, drones are already used in restricted areas for urgent city rapid parcel delivery, live monitoring to navigate easily through traffic situations, and fast relief in emergency cases. This development allows us to state confidently that drones have operational capacities to smooth the transportation process, accelerate the conveyance process, and deliver a transpiration smart economies model.

Table 1: Sample of key informants interviewed

Interviewee title	Type of organization	Number of interviewees	Reason for selection
Government official in transportation department	Government	6	To gain insights into regulatory perspectives, policy development, and governmental support for drone technology in logistics
CEO of a drone technology firm	Private sector - technology company	7	To understand the technological advancements, market readiness, and practical challenges of implementing drone logistics solutions
Director of sustainable development, international organization	International non-governmental organization (NGO)	5	To explore the alignment of drone logistics with global sustainable development goals and ESE principles
Academic researcher in logistics and supply chain management	Academic institution	8	To acquire theoretical and empirical knowledge on the impact of drone technology on logistics and supply chain efficiencies
Logistics manager of a leading retail company	Private sector - retail	5	To assess the practical implications, benefits, and logistical challenges of integrating drone technology in retail logistics
Technology policy analyst	Think tank	7	To understand the policy landscape, regulatory challenges, and future trends in drone technology and logistics
Environmental consultant	Environmental consultancy	4	To evaluate the environmental impacts and contributions of drone technology to ESE objectives within the logistics sector

Table 2: Questions asked during semi-structured interviews

Topic/theme	Discussed questions	Follow-up questions
Overview of drone usage in logistics and transportation	Primary applications, challenges, and advantages	Specific missions where drones are currently utilized
Regulations and laws governing drone use	Evolution of regulations over time	Impact of changes on drone usage
Corporate utilization of drones in logistics	Trends and challenges in drone adoption	Examples of companies using drones and for what purposes
Future prospects for drone usage	Potential technological advancements	Predictions for drone integration into logistics and transportation
Lessons from drone implementation	Major takeaways from countries with advanced drone usage	Considerations for countries planning to integrate drones
Impact on customer service and delivery times	Effects of drones on operational efficiency	Comparisons with traditional delivery methods
Cost-benefit analysis of drones versus traditional logistics	Economic considerations	Efficiency and effectiveness of drones compared to conventional methods
Job market impact due to drones in logistics	Changes in employment types and numbers	New opportunities versus job displacement
Obstacles to widespread drone use in logistics	Technical, regulatory, and infrastructural challenges	Strategies to overcome these barriers
Safety and security measures for drones	Protocols to ensure the secure operation of drones	Preventive measures against accidents and misuse
Technological advancements enabling drone use	Innovations in drone technology	Contributions to logistics and transportation efficiency
Role of drones in last-mile delivery	Efficiency of drones in final delivery stages	Comparison with other delivery methods
Drones in urban traffic management	Usage in improving traffic flow and reducing congestion	Benefits and limitations of drones in traffic monitoring
Drones in transportation of hazardous materials and medical supplies	Safety, efficiency, and regulatory considerations	Examples of successful drone usage in medical logistics
Drones in disaster relief and humanitarian aid	Efficiency of drones in emergency situations	Impact on response times and resource allocation
Drones in remote and rural area access	Benefits of drones in enhancing service delivery in isolated areas	Examples of drone applications in remote logistics and service provision
Privacy and legal considerations in drone usage	Impact of drones on privacy and legal norms	Measures to align drone operations with privacy laws

There is a long and difficult path to be traversed for integrating drone technology in Jordan's logistics sector. Among the challenges, one should note the common issue of regulatory barriers, which are difficult to overcome. These include finding a compromise between the development of a new invention and safety and privacy considerations. Authorities in Jordan (and worldwide) are particularly concerned with incorporating drones into airspace safely. The dynamic nature of the given field implies forever changing guidelines, making businesses liable for standard changes as well.

Another major constraint in the deployment of drones is fundamental technological issues, particularly power requirements relative to functional capabilities. For instance, drones have limited capacity to carry heavy loads over long distances without stopping to recharge. At the current juncture, this limitation makes

Table 3: Semi-structured interview results

Topic/theme	Dimensions	Quote
Overview of drone usage	Package delivery, inventory management, surveillance, and emergency response`	"Drones are increasingly adopted for rapid parcel delivery and real-time traffic monitoring"
Regulatory landscape	Safety, airspace management, and privacy	"Regulations vary by country, focusing on safety and privacy"
Corporate utilization and trends	Mapping, inspection, delivery, automation, artificial intelligence (AI), and internet of things (IoT) integration	"Companies use drones for tasks like mapping and delivery, with trends toward automation"
Future prospects	Extended beyond visual line of sight (BVLOS) operations, and urban air mobility	"Prospects include extended BVLOS operations and urban air mobility"
Lessons from other countries	Regulatory frameworks, collaboration, and innovation	"Comprehensive regulatory frameworks and innovation are key to successful drone integration"
Impact on customer service and delivery times	Service speed and efficiency	"Drones enhance service speed, especially in challenging terrain"
Cost-benefit analysis	Long-term savings and efficiency benefits	"Drones offer long-term savings in surveillance and targeted deliveries"
Employment implications	Technical and specialized roles	"The drone industry shifts job opportunities toward technical roles"
Widespread adoption challenges	Regulatory compliance, public perception, and infrastructure	"Barriers to adoption include regulatory compliance and public perception"
Safety and security measures	Pilot training, safety features, and public awareness	"Pilot training and safety features are critical for safe drone operations"
Technological advances	Materials, power systems, navigation, and data analytics	"Advancements in navigation and data analytics are driving drone capabilities"
Role in last-mile delivery	Efficiency in delivery	"Drones offer benefits for efficient last-mile delivery in suitable environments"
Urban traffic and congestion management	Traffic monitoring and congestion reduction	"Drones are tested for traffic monitoring to reduce congestion"
Transportation of hazardous materials and medical supplies	Safety protocols and rapid transport	"Drones provide solutions for the safe transport of critical supplies"
Disaster relief and humanitarian aid	Rapid response, assessment, and aid delivery	"Drones are valuable for rapid response and aid delivery in disaster situations"
Improving access in remote areas	Connectivity and support in remote regions	"Drones improve access to goods and services in remote regions"

AI: Artificial intelligence, IoT: Internet of things, BVLOS: beyond visual line of sight

it impossible for drones to replace vehicles and overturn public transport as the primary means of transporting goods over long distances (e.g., between cities in Jordan). Nevertheless, while they are of negligible utility for mass transportation and haulage, drones may be used to transport goods in urgent cases.

On the other hand, many concerned citizens may become skeptical of drones flying over their heads, which may raise privacy and security concerns, including the drone recording data. This necessitates the implementation of stringent security measures and ensuring that the community is well-informed to boost their trust in technology.

However, drones have an overall transformative potential for Jordan's logistics and transportation industry. They are more than just a quick and affordable solution for particular cases; drones can be applied for multiple needs and tasks in the logistics process. They can penetrate otherwise inaccessible areas, provide information for quick decisions in real-time, and most importantly, eliminate the element of unnecessary burden related to the logistics and transportation process.

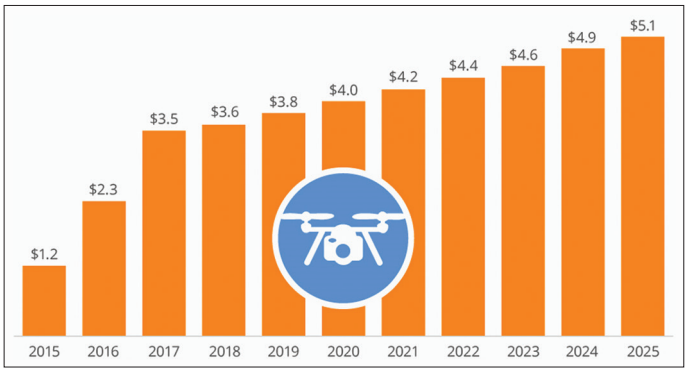
Given the complexity of the challenges mentioned, the effective incorporation of drones into Jordan's logistics and transportation system is only possible when the effort is coordinated between government bodies, technology developers, and logistics organizations. In terms of regulation, drone technology must be utilized safely and cost-effectively, the subject of the technology must be well-developed, and the human factor at the managerial level must be considered.

To conclude, drones are leading the change in the logistics and transportation segment of Jordan. Through the use of technological innovation and driving collaborative initiatives to overcome existing hurdles, drones can serve as new, efficient, sustainable, and agile solutions for logistics and transportation, epitomizing the implementation of ESE in Jordan.

5. DISCUSSION

The research findings detailed the transformative ability of The research findings illustrate the transformative potential of sustainable drone technology in Jordan's logistics sector, as provided by ESE. This approach integrates sustainable development, economic optimization, and environmental protection, aiming to achieve economic growth while adhering to principles of ecological rationality. Drones have been identified as a significant factor in enhancing the operational efficiency of Jordan's logistics sector (Raj and Sah, 2019). The study found that drones significantly reduce delivery times and operating costs (Nentwich and Horváth, 2018; Chiang et al., 2019). Additionally, because drones operate on electricity and their flight paths are designed to minimize carbon emissions, they align with global movements towards environmentally sustainable logistics

Figure 8: The economic impact of drone sector in the United States (billion USD) (Statista, 2024b)



(Goodchild and Toy, 2017). However, the implementation of drones faces legislative, privacy, technological, and security challenges. Echoing the findings of Sah et al. (2021), the current study emphasizes the need for regulators to balance innovation with public safety and privacy. Navigating this balance is crucial for the sustainable and secure use of drone-based logistics.

The study also underscores the importance of continuous technological development and supportive governmental policies in the integration of drones, corroborating the conclusions of Eskandaripour and Boldsaikhan (2023). Policymakers must create a regulatory environment that fosters innovation while addressing safety and privacy concerns, ensuring the effective deployment of drone technology in logistics. Moreover, the socio-economic implications of drone technology, such as job creation and service enhancement in remote areas, are increasingly recognized, although empirical studies remain limited. Li et al. (2022) provided examples of the positive socio-economic effects of drones, supporting the broader objectives of ESE by promoting socio-economic development in Jordan. This aligns with previous findings on the beneficial impact of the commercial drone sector in the United States, as depicted in Figure 8.

In summary, this study provides a holistic framework for implementing drone technology in the Jordanian logistics sector, encompassing technological advancements, regulatory improvements, and socio-economic considerations. Strategic measures and international cooperation, involving diverse local and global stakeholders, are essential to ensure sustained growth and advancement in line with the principles of ESE

6. CONCLUSIONS

The findings of this study have unveiled the groundbreaking and transformative implications of the use of sustainable drone technology in reshaping the logistics landscape of Jordan in accordance with the governing principles of ESE. Drones, as a mode of transport, can drastically increase operational efficiencies while ensuring the environmental footprint is adequately minimized. Additionally, the automation facilitated by drones can help spur economic development. These results emphasize the prerequisite need for supportive regulatory requirements and relentless technological development to utilize the full potential offered by drones. Furthermore, the study identified the barriers to seamless drone integration: restrictive regulation, technological limitations, as well as the public's apprehension over privacy and safety.

To overcome these challenges, a coordinated effort among policymakers at the governmental level, businesses, and technology experts must be undertaken to facilitate drone logistics. Jordan can utilize sustainable drone technology as a tool to become the most innovative producer of eco-smart logistics and contribute to the global understanding of sustainable development. Administration efforts should include large-scale pilot projects to test and succeed with drone use in logistics, the promotion of public-private partnerships to establish innovation in the field, and the development of prerequisites for innovative policies allowing technology enhancement under the control of safety and privacy, consulting and including diverse stakeholder groups to enable sustainable long-term development.

Future researchers interested in the application of drone technology in Jordan can explore several promising areas to further enhance its integration and effectiveness. One critical avenue is the development of advanced regulatory frameworks that balance innovation with safety and privacy concerns, ensuring that drone operations can expand without compromising public trust or security. Additionally, future research should focus on improving the technological capabilities of drones, such as extending battery life, increasing payload capacities, and enhancing autonomous navigation systems to better suit the diverse and often challenging terrain of Jordan. The socioeconomic impacts of drone technology also warrant further investigation, particularly in terms of job creation, service enhancement in remote areas, and overall contributions to economic development. Finally, large-scale pilot projects and public-private partnerships could be instrumental in demonstrating the practical benefits of drones, fostering innovation, and guiding policy development.

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