How long before Take-off? Sociotechnical Enablers and Barriers to UAVs Logistics

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Abstract: According to the literature, Unmanned Aerial Vehicles (UAVs) promise to improve logistics processes, as they are environmentally friendly, provide an economic advantage and improve delivery services simultaneously.

However, existing research has primarily focused on the operational aspects of UAVs technology, neglecting a comprehensive understanding of the enablers and barriers to its adoption from a sociotechnical perspective. The current state-of-the-art provides a limited overview of this technology's enablers and barriers, by focusing only on the technological and regulatory elements, as well as consumers' social acceptance, while disregarding the significance of human-technology interactions in UAVs adoption. It is crucial to view UAVs as "disruptive socio-technical systems" and consider the intricate relationship between humans and technology when studying their adoption. Drawing on the sociotechnical system (STS) theory and focusing on middle- and last-mile logistics, this study recognizes UAVs adoption as a complex system that necessitates the examination of its social and technological components. The analysis employs six key elements: people, goals, processes, infrastructures, culture, and technology.

Therefore, to contribute to fill this literature gap, we develop a preliminary framework through a systematic literature review that identifies the enablers and barriers to UAVs adoption and categorizes them according to the six elements of the STS theory. This framework also examines the impact of UAVs adoption on humans, particularly logistics workers, within the context of logistics processes.

This study offers both theoretical and managerial contributions. On the one hand, it applies the STS theory to middle- and last-mile logistics and the UAVs technology domain. On the other hand, it provides a holistic STS analysis of the middle- and last-mile logistics system, offering a comprehensive understanding of the enablers and barriers to the adoption of UAVs technology. This comprehensive perspective can encourage practitioners to adopt UAVs by addressing their concerns beyond individual issues such as regulations and financial feasibility, and by considering the overall sociotechnical impacts of technology usage, including the effects of UAVs on logistics workers.

Keywords: Enablers and barriers, Middle- and last-mile logistics, Sociotechnical systems theory, Systematic literature review, Unmanned aerial vehicles

I. INTRODUCTION

Due to the rise of e-commerce and globalization, the transportation sector has experienced exponential growth [1] over the last two decades, leading supply chains (SCs) to look for novel alternatives to best serve customers.

In particular, the middle-mile (i.e., "the part of the SC where goods are shipped from warehouses or distribution centers to retail stores or fulfillment centers" [2]) and last-mile (i.e., "the last stretch of a […] delivery service", from the order penetration point to the final customer [3]) segments are in dire need of improvements as they are currently facing several challenges, such as the increase in externalities (i.e., air pollution, climate change, noise pollution, traffic congestion, etc. [4]) and customer expectations (e.g., improved reliability and faster delivery) [5], various inefficiencies [6] (e.g., the last-mile segment amounts to 28% of delivery costs of the supply chain [7]), and the shortage of truck drivers [8]. This trend was further pushed by the outbreak of COVID-19, which highlighted the necessity for a delivery system to provide a fast, resilient, and safe contactless solution to easily reach isolated or quarantined areas

[9]. Thus, it is understandable that companies look for sustainable, efficient, and resilient delivery solutions to remain competitive.

Unmanned aerial vehicles (UAVs) are among the most studied technologies in the last few years with reference to middle- and last-mile logistics [10], offering a potential solution to the challenges mentioned above [11]. UAVs are equipped with specific software and integrated GNSS and can be remotely piloted or fly automatically [12].

The use of UAVs in logistics has been studied in the literature from different perspectives. Most research focused on vehicle routing problems [13]–[16] or other optimization problems (e.g., facility location, scheduling, and delivery network design) [17]. Only a very limited array of papers provided a view on the enablers and barriers of UAVs adoption in logistics, e.g., identifying the strengths and challenges of employing UAVs in logistics, mainly focusing on technical elements [18] or investigating the potential problems and solutions of this technology without focusing specifically on logistics and distribution processes [19]. However, currently existing literature disregards the significance of (so-called) human-technology interactions (as defined in sociotechnical literature [20]) in UAVs adoption (e.g., interactions between pilots and UAVs, human workers loading/unloading UAVs), which is a crucial aspect [21] for business success to consider both social and technical aspects in the design and management of UAV-enabled logistics systems [22]. To properly study the elements of human-technology interactions, the sociotechnical system (STS) theory is employed as a theoretical lens to properly evaluate the relationship between the social and technological elements of UAVs adoption.

Currently, logistics practitioners need more knowledge and tools to properly evaluate UAVs' adoption, considering this technology's sociotechnical complexity. Therefore, to empower logistics practitioners with a deeper understanding of the factors influencing the adoption of UAVs in their middle- and last-mile logistics processes, a preliminary framework is developed through a systematic literature review (SLR) to categorize enablers and barriers to UAVs adoption according to a sociotechnical perspective.

This study will answer the following research question (RQ):

How can current enablers and barriers to UAVs adoption in middle- and last-mile logistics processes be categorized through a sociotechnical perspective?

The remainder of this paper is organized as follows: Section 2 presents the research background, while Section 3 describes the methodology adopted. The findings are presented and discussed in Section 4. Lastly, Section 5 summarizes the conclusions and future research directions.

II. RESEARCH BACKGROUND

A. Unmanned Aerial Vehicles

UAVs (a.k.a. drones) have initially emerged in the military sector but spread in the last 10 to 15 years to civil adoption. They are employed or tested in aerial photography, monitoring, agriculture, logistics, and healthcare [23]. The logistics sector has developed a particular interest in this technology due to its peculiar potential, such as representing a green alternative to traditional vehicles, promising deliveries without contact with the final customer [24] regardless of the destination's location [25], and reducing overall transportation costs [26]. Many logistics companies started experimenting with this technology. In 2013, for example, Amazon announced Prime Air [27], a service that utilizes multirotor UAVs to deliver packages from Amazon to customers, while Deutsche Post DHL launched its Parcelcopter project [28]. Google revealed Project Wing [29] in 2014 to produce UAVs that can carry more oversized items than Prime Air and Parcelcopter [30].

B. Sociotechnical Systems Theory

According to the literature it is crucial to view UAVs as "disruptive socio-technical systems" and consider the intricate relationship between humans and technology when studying their adoption [31]. This aligns with other authors' claims that systems complexity is increasing, thus leading researchers and practitioners to adopt a holistic point of view to develop and implement STSs properly [32]. Therefore, focusing not only on the systems' elements and their interactions but also on the relationships of these interactions [33]. This is extremely important in the context of STSs, as the proper development of both social and technical elements will lead to its "successful (or unsuccessful) system performance" [33]. STS theory considers organizations as complex systems that must be studied through their social and technological components and the relationships among them. This analysis is performed through six elements, i.e., people, culture, technology, infrastructure, goals, and procedures [34].

III. METHODOLOGY

To answer the research question, a SLR spanning from 2013 (i.e., when project Amazon Prime Air was first announced [27]) to April 2023 was conducted on the enablers and barriers to UAVs adoption in middle- and last-mile logistics and analyzed through the lens of STS theory. The SLR employed the following steps to perform rigorous research and increase its replicability.

A. Preliminary Literature Search

The objective of the first step was to get accustomed to the research topics, which in this case are:

- Unmanned Aerial Vehicles
- Middle- and last-mile logistics
- Sociotechnical systems theory

Once the seminal papers were identified, the following pieces of information on the research's topic were collected:

- An unambiguous definition.
- Most commonly employed keywords.

B. Search Protocol

To maximize the effectiveness of the literature search, this SLR employed both Scopus and Web of Science databases since they are defined as the largest for peer-reviewed literature [12].

A "three-level query" [35] was developed using the most commonly employed keywords (i.e., including synonyms identified in the previous step, thus avoiding excluding relevant literature), i.e., 1) technological (i.e., UAV and its synonyms) - "drone" OR "UAV" OR "unmanned aerial vehicle" OR "remotely piloted aircraft" OR "autonomous delivery device" –, 2) contextual (i.e., the middle- and last-mile logistics contexts) – "middle mile" OR "last mile" OR "logistics" OR "deliver*" OR "transport*" –, and 3) analytical (i.e., enablers and barriers) - "factor" OR "influenc* factor" OR "driver" OR "enabl*" OR "barrier".

Papers were identified and selected according to specific inclusion and exclusion criteria (see Table I). During the screening phase, titles and abstracts were read, while during the eligibility phase, the full texts of the paper were read. The number of papers initially identified for the query was too large to manually screen (i.e., 2,158 results on Scopus and 1,930 results on Web of Science). Therefore, the following restrictions were added: language (English) and only journal articles. A further limitation on the included subject areas was added: Social Sciences; Decision Sciences; Business, Management, and Accounting; Multidisciplinary; Psychology.

TABLE I
INCLUSION AND EXCLUSION CRITERIA

Screening Phase		
Inclusion	Papers discussing UAVs and middle- or last-mile logistics	84
Exclusion	Papers out of research theme (i.e., not focused on UAV logistics)	655
Eligibility Phase		
Inclusion	Papers that provide information on the enablers and barriers to adopting UAVs in the middle- or last-mile logistics	42
Exclusion	Papers out of research scope (i.e., articles with no clear contribution on enablers and barriers on UAVs)	42

While reading titles and abstracts, 655 papers were excluded during the screening phase because they did not focus on UAVs in the context of logistics. In the eligibility phase, 42 papers were excluded because they did not provide information on enablers or barriers to UAV logistics. Ultimately, a total of 42 papers were included in this SLR.

C. Conceptual Review

Lastly, a conceptual review was performed to highlight the main enablers and barriers to adopting UAVs in middle- and last-mile logistics and categorize them according to the six elements of STS.

IV. FINDINGS AND DISCUSSION

To better understand why enablers and barriers were categorized according to the STS theory, a generic last-mile delivery process [30] is taken into consideration. Starting from the order penetration point, goods are assigned to a specific customer and transported to the dedicated delivery point. This process can be split into three main stages: The warehouse operators prepare the goods to be delivered and load them into the assigned vehicle. Employing UAVs, warehouse workers must arrange several smaller packages to be loaded on the correct UAV. The UAV then follows the optimal route programmed for that specific delivery, either remotely guided by a pilot or autonomously. Depending on the trip distance, it may have to interact with a recharging station to replenish its batteries. Lastly, the UAV safely delivers the package to the destination, interacting with the final consumer or another operator.

This process can be described through the lens of STS [36]: There are several *people* (i.e., warehouse workers, UAV pilots, final consumers) who pursue different *goals* (i.e., preparing the goods and loading the vehicle, safely transporting the goods, and acquiring the packages) according to specific *procedures*. Each interacts with or uses several *technologies* (e.g., UAVs) and *infrastructures* (i.e., distribution centers, recharging stations, and delivery points). This occurs "within the organization's local culture, which is then set within larger professional and national cultures" [36].

This example further highlights the sociotechnical characteristics of the logistics system, which requires the holistic perspective provided by the STS theory. Thus, it is possible to notice that the successful development of this STS comes from a correct balance of both "social" and "technical" aspects analysis [22]. Therefore, the factors affecting the adoption of UAVs for middle- and last-mile logistics were classified according to the six elements of STS theory and divided into enablers (Table II) and barriers (Table III).

A. Goals

Several elements represent enablers of UAVs adoption in the middle- and last-mile logistics. The latter is considered the most inefficient stage of the SC due to its high costs and impact on air pollution [2]–[5]. Problems that are relevant also for the middle-mile segment [4]. The adoption of UAVs could reduce costs [37, 38] thanks to the concept of "one-to-many operations" (i.e., requiring a lower number of pilots to manage multiple drones – a concept of operations in its experimental stage), being less expensive than last-mile traditional vehicles, and being even more energy-efficient than other electric vehicles (e.g., e-cargo bikes and electric vans) in certain scenarios (i.e., employed to service vast and scarcely populated areas) [7]. Furthermore, the transportation process would also achieve greater sustainability, both directly (e.g., due to the electric nature of the technology) and indirectly (e.g., thanks to a reduction of ground traffic congestion) [17]. Time savings are another recurrent enabler in the analyzed literature [39],

TABLE II
UAV LOGISTICS ENABLERS ACCORDING TO STS THEORY

STS	ENABLERS	REFERENCES*
GOALS	Improved service Increased competitiveness Time savings Cost-effectiveness Reduced carbon footprint	Ali *et al.* (2023), Aurambout *et al.* (2022), Aurambout *et al.* (2019), Buldeo *et al.* (2022), Demir *et al.* (2022), Dong *et al.* (2021), Karakikes and Nathanail (2020), Liang and Luo (2022), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Raj and Sah (2019), Rathore *et al.* (2022), Rombaut and Vanhaverbeke (2021), Zenezini *et al.* (2022)
PEOPLE	Consumers' perception	Cai *et al.* (2021), Chen *et al.* (2022), EASA (2021), Eißfeldt *et al.* (2020), Ganjipour and Edrisi (2023), Hwang *et al.* (2019), Hwang and Kim (2021), Kahler *et al.* (2022), Khalil *et al.* (2022), Koh *et al.* (2023), Li and Janabi-Sharifi (2022), Mathew *et al.* (2021), Osakwe *et al.* (2022), Rengarajan *et al.* (2017), Sabino *et al.* (2022), Zhu *et al.* (2020)
PROCEDURE	Dynamic orders Scheduling	Ali *et al.* (2023), Buldeo et al. (2022), Dong *et al.* (2021), Liang and Luo (2022), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Rathore *et al.* (2022), Sah *et al.* (2021), Zenezini *et al.* (2022)
INFRASTR.	Independence from road infrastructure	Demir *et al.* (2022), Raj and Sah (2019), Rathore *et al.* (2022), Zenezini *et al.* (2022)
TECHNOLOGY	Autonomous Speed Flexible Energy-efficient	Ali *et al.* (2023), Aurambout *et al.* (2022), Buldeo et al. (2022), Demir *et al.* (2022), Dong *et al.* (2021), Ganjipour and Edrisi (2023), Khalil *et al.* (2022), Liang and Luo (2022), Mathew *et al.* (2021), Merkert and Bushell (2020), Mohammad *et al.* (2023), Osakwe *et al.* (2022), Perussi *et al.* (2019), Raj and Sah (2019), Rathore *et al.* (2022), Sah *et al.* (2021), Watkins *et al.* (2020), Zenezini *et al.* (2022)
CULTURE	Improved sustainability Innovation-driven Public acceptance	Ali *et al.* (2023), Aurambout *et al.* (2022), Buldeo et al. (2022), Chung *et al.* (2020), Demir *et al.* (2022), Dong *et al.* (2021), Karakikes and Nathanail (2020), Lockhart *et al.* (2021), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Sah *et al.* (2021), Zenezini *et al.* (2022)

which would lead to an overall improvement of the service offered and consequent competitive advantage [40]. However, the complexity of this technological solution and its initial high costs could lead to an erosion of said competitive advantage [38].

B. People

There is a potential gap concerning the individual stakeholders directly related to the logistics process. Even though several people are directly involved in the process (e.g., logistics operators, pilots, and consumers – as proposed in the example provided at the beginning of this section), most authors focused on studying the final consumers' acceptance. Several surveys have been conducted to identify the perception of this technology and potential factors influencing the adoption of this technology from the consumers' perspective. For example, [40] performed a survey in South Korea about the public acceptance of drones for food delivery. The results showed that customers expect an improved service in terms of a cheaper, faster, and greener delivery due to UAVs' characteristics. These enablers were confirmed by [37], who divided the relevant factors to the adoption of UAVs in logistics from the customers' perspective into three categories (i.e., socio-cultural influences, main perceived risks, and main expected benefits). The authors further identified some barriers, such as privacy violations, noise, safety, and legal liability. Enablers and barriers related to consumers' perception of drone delivery were also confirmed by a study for societal acceptance of advanced air mobility conducted by EASA [41].

C. Procedure

Several authors highlighted that UAVs could bring significant advantages to route scheduling thanks to their flexibility and increased speed in fulfilling customers' orders (i.e., dynamic order routing) [42]. However, certain barriers should be prioritized, the most important one being regulations, which would limit the operations of this technology in areas of urban and airport activities [17], [43]–[45]. Planning issues (i.e., the increased complexity of planning routes) and lack of authorization are other relevant barriers.

D. Infrastructure

On the one hand, the independence of UAVs from ground infrastructures provides flexibility, speed, and the possibility to reach inaccessible areas easily [40].

TABLE III
UAV LOGISTICS BARRIERS ACCORDING TO STS THEORY

STS	BARRIERS	REFERENCES*
GOALS	Applicability Complexity	Ali *et al.* (2023), Aurambout *et al.* (2022), Aurambout *et al.* (2019), Buldeo *et al.* (2022), Demir *et al.* (2022), Dong *et al.* (2021), Karakikes and Nathanail (2020), Liang and Luo (2022), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Raj and Sah (2019), Rathore *et al.* (2022), Rombaut and Vanhaverbeke (2021), Zenezini *et al.* (2022)
PEOPLE	Consumers' perception	Cai *et al.* (2021), Chen *et al.* (2022), EASA (2021), Eißfeldt *et al.* (2020), Ganjipour and Edrisi (2023), Hwang *et al.* (2019), Hwang and Kim (2021), Kahler *et al.* (2022), Khalil *et al.* (2022), Koh *et al.* (2023), Li and Janabi-Sharifi (2022), Mathew *et al.* (2021), Osakwe *et al.* (2022), Rengarajan *et al.* (2017), Sabino *et al.* (2022), Zhu *et al.* (2020)
PROCEDURE	Lack of authorization Planning issues Regulations	Ali *et al.* (2023), Buldeo et al. (2022), Dong *et al.* (2021), Liang and Luo (2022), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Rathore *et al.* (2022), Sah *et al.* (2021), Zenezini *et al.* (2022)
INFRASTR.	Infrastructural requirements	Demir *et al.* (2022), Raj and Sah (2019), Rathore *et al.* (2022), Zenezini *et al.* (2022)
TECHNOLOGY	Technical limitations Data collection Misuse Technical failures Theft Air traffic	Ali *et al.* (2023), Aurambout *et al.* (2022), Buldeo et al. (2022), Demir *et al.* (2022), Dong *et al.* (2021), Ganjipour and Edrisi (2023), Khalil *et al.* (2022), Liang and Luo (2022), Mathew *et al.* (2021), Merkert and Bushell (2020), Mohammad *et al.* (2023), Osakwe *et al.* (2022), Perussi *et al.* (2019), Raj and Sah (2019), Rathore *et al.* (2022), Sah *et al.* (2021), Watkins *et al.* (2020), Zenezini *et al.* (2022)
CULTURE	Not commercialized yet Wildlife harming Public perception	Ali *et al.* (2023), Aurambout *et al.* (2022), Buldeo et al. (2022), Chung *et al.* (2020), Demir *et al.* (2022), Dong *et al.* (2021), Karakikes and Nathanail (2020), Lockhart *et al.* (2021), Merkert and Bushell (2020), Mohammad *et al.* (2023), Perussi *et al.* (2019), Sah *et al.* (2021), Zenezini *et al.* (2022)

On the other hand, this technology requires considerable initial investments in infrastructural elements necessary to employ this technology, such as landing pads and recharging stations [38], as well as careful considerations on the design of urban areas (e.g., low building density to improve drones' navigation and reduce collision risks).

E. Technology

As far as the technology itself is concerned, several enablers linked to its characteristics were identified. Time savings are achieved by the ability of UAVs to avoid traffic congestion, fly over any obstacles, and generally be independent of conventional transportation infrastructures [40]. The latter shows one of the most impactful characteristics of this technology: the possibility to deliver almost anywhere [38]. This opens up the possibility of offering logistics services in challenging-to-reach or inaccessible regions by road transport, thus increasing the serviced area and drastically reducing delivery costs [37].

However, the currently existing technical limitations are among the most highlighted barriers [16, 42]. Most authors mentioned a small flying range related to battery limits, a restricted payload, and dependence on weather conditions [38].

F. Culture

Logistics companies are adopting green practices to achieve their sustainability objectives, driven by innovation. However, some barriers might need to be considered. One of the most mentioned issues concerns the public perception of this technology [39], which is perceived as a potential risk to privacy and safety [42]. Other authors raised issues about the possible noise and legal liability in case of accidents [37]. Some authors mentioned that surveys about public perception should be repeated once more when this technology is commercialized [40]. Lastly, it was mentioned that drones could represent a possible danger to wildlife [45], as animals could change their behavior in the presence of an unnatural object and possibly be harmed by it (e.g., UAVs' blades hurting avian species).

V. CONCLUSIONS

SCs are currently struggling due to several challenges, such as urbanization, climate change, and disruptions caused by unexpected events. Most of this pressure is put on the logistics systems, such as the middle- and last-mile segment, often described as the most inefficient stage of a SC. Many researchers have started to study the potential benefits of UAVs to cope with these challenges. Their characteristics make them a possible solution to these struggles, as they are often described as fast, flexible, cheap, and green. However, most researchers have focused on specific impacts that UAVs could have logistics processes (i.e., economic, social, and environmental), neglecting a holistic perspective in the analysis of the problem. Therefore, a comprehensive point of view (i.e., tackling all aspects and elements of the logistics system) on adopting UAVs is understudied, leading logistics practitioners to lack the knowledge and tools to properly understand and evaluate the adoption of UAVs in their logistics processes.

To address this gap, this work performed a SLR to identify the enablers and barriers to UAVs adoption. Thus, a preliminary framework on enablers and barriers in the middle- and last-mile logistics was developed, categorized under the six elements of STS: goals, people, procedure, infrastructure, technology, and culture, which provides theoretical and managerial contributions.

Future research could validate and refine the preliminary framework using empirical methodologies (e.g., focus groups, case studies). Furthermore, future research on the impact of UAVs on other stakeholders (e.g., logistics workers, UAV pilots) could be performed by shifting the analysis from a technology-focused perspective, as it was predominantly performed so far, to more a human-centered focus (i.e., considering the effect that UAVs have on the workers who are directly in contact with the technology). Lastly, further analysis of the relationships among the six elements of the STS studied here could provide additional interesting insights.

VI. REFERENCES

** The complete list of references for the papers included in this SLR is available upon request.*

[1] Ranieri, L. *et al.* (2018) 'A review of last mile logistics innovations in an externalities cost reduction vision', *Sustain.*, 10(3), pp. 1–18. doi: 10.3390/su10030782.

[2] DHL (2021) 'DHL WHITE PAPER - ECO-MMERCE', (June). Available at: https://www.dhl.com/content/dam/dhl/local/us/core/documents/pdf/us-core-white-paper-ecommerce.pdf.

[3] Lim, S. F. W. T., Jin, X. and Srai, J. S. (2018) 'Consumer-driven e-commerce: A literature review, design framework, and research agenda on last-mile logistics models', *Int. J. Phys. Distrib. Logist. Manag.*, 48(3), pp. 308–332. doi: 10.1108/IJPDLM-02-2017-0081.

[4] van Essen, H. *et al.* (2019) *Handbook on the External Costs of Transport, Report for the European Commission*. Delft: CE Delft. doi: 10.2832/51388.

[5] Salama, M. and Srinivas, S. (2020) 'Joint optimization of customer location clustering and drone-based routing for last-mile deliveries', *Trans. Res. Part C*, 114(July 2019), pp. 620–642. doi: 10.1016/j.trc.2020.01.019.

[6] Perboli, G. and Rosano, M. (2019) 'Parcel delivery in urban areas: Opportunities and threats for the mix of traditional and green business models', *Trans. Res. Part C*, 99(January), pp. 19–36. doi: 10.1016/j.trc.2019.01.006.
[7] Wang, Y. *et al.* (2016) 'Towards enhancing the last-mile delivery: An effective crowd-tasking model with scalable solutions', *Trans. Res. Part E*, 93, pp. 279–293. doi: 10.1016/j.tre.2016.06.002.
[8] Ji-Hyland, C. and Allen, D. (2022) 'What do professional drivers think about their profession? An examination of factors contributing to the driver shortage', *Int. J. Logist. Res. Appl.*, 25(3), pp. 231–246. doi: 10.1080/13675567.2020.1821623.
[9] Kim, J. J., Kim, I. and Hwang, J. (2021) 'A change of perceived innovativeness for contactless food delivery services using drones after the outbreak of COVID-19', *Int. J. Hosp. Manag.*, 93(June 2020), p. 102758. doi: 10.1016/j.ijhm.2020.102758.
[10] DHL (2023) 'The Logistics Trends Radar', pp. 1–152. Available at: https://www.dhl.com/content/dam/dhl/global/csi/documents/pdf/csi-logistics-trend-radar-6-dhl.pdf.
[11] Lemardelé, C. *et al.* (2021) 'Potentialities of drones and ground autonomous delivery devices for last-mile logistics', *Trans. Res. Part E*, 149(April). doi: 10.1016/j.tre.2021.102325.
[12] Rashidzadeh, E. *et al.* (2021) 'Assessing the sustainability of using drone technology for last-mile delivery in a blood supply chain', *J. Model. Manag.*, 16(4), pp. 1376–1402. doi: 10.1108/JM2-09-2020-0241.
[13] Macrina, G. *et al.* (2020) 'Drone-aided routing: A literature review', *Trans. Res. Part C*, 120(September), p. 102762. doi: 10.1016/j.trc.2020.102762.
[14] Rojas Viloria, D. *et al.* (2021) 'Unmanned aerial vehicles/drones in vehicle routing problems: a literature review', *Int. Trans. Oper. Res.*, 28(4), pp. 1626–1657. doi: 10.1111/itor.12783.
[15] Chung, S. H., Sah, B. and Lee, J. (2020) 'Optimization for drone and drone-truck combined operations: A review of the state of the art and future directions', *Comput. Oper. Res.*, 123, p. 105004. doi: 10.1016/j.cor.2020.105004.
[16] Li, H. *et al.* (2021) 'Ground-vehicle and unmanned-aerial-vehicle routing problems from two-echelon scheme perspective: A review', *Eur. J. Oper. Res.*, 294(3), pp. 1078–1095. doi: 10.1016/j.ejor.2021.02.022.
[17] Benarbia, T. and Kyamakya, K. (2022) 'A literature review of drone-based package delivery logistics systems and their implementation feasibility', *Sustain.*, 14(1), pp. 1–15. doi: 10.3390/su14010360.
[18] Rejeb, A. *et al.* (2021) 'Drones for supply chain management and logistics: a review and research agenda', *Int. J. Logist. Res. Appl.*, 0(0), pp. 1–24. doi: 10.1080/13675567.2021.1981273.
[19] Kellermann, R., Biehle, T. and Fischer, L. (2020) 'Drones for parcel and passenger transportation: A literature review', *Transp. Res. Interdiscip. Perspect.*, 4, p. 100088. doi: 10.1016/j.trip.2019.100088.
[20] Karwowski, W. (2005) 'Ergonomics and human factors: The paradigms for science, engineering, design, technology and management of human-compatible systems', *Ergonomics*, 48(5), pp. 436–463. doi: 10.1080/00140130400029167.
[21] Winkelhaus, S., and Grosse, E. H. (2020). 'Logistics 4.0: a systematic review towards a new logistics system'. International Journal of Production Research, 58(1), 18-43. doi: 10.1080/00207543.2019.1612964
[22] Sgarbossa, F. *et al.* (2020) 'Human factors in production and logistics systems of the future', *Annu. Rev. Control*, 49, pp. 295–305. doi: 10.1016/j.arcontrol.2020.04.007.
[23] Hii, M. S. Y., Courtney, P. and Royall, P. G. (2019) 'An evaluation of the delivery of medicines using drones', *Drones*, 3(3), pp. 1–20. doi: 10.3390/drones3030052.
[24] Chamola, V. *et al.* (2020) 'A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact', *IEEE Access*, 8(April), pp. 90225–90265. doi: 10.1109/ACCESS.2020.2992341.
[25] Choi, Younghoon *et al.* (2019) 'A multi-trip vehicle routing problem for small unmanned aircraft systems-based urban delivery', *J. Aircr.*, 56(6), pp. 2309–2323. doi: 10.2514/1.C035473.
[26] Rabta, B., Wankmüller, C. and Reiner, G. (2018) 'A drone fleet model for last-mile distribution in disaster relief operations', *Int. J. Disaster Risk Reduct.*, 28(February), pp. 107–112. doi: 10.1016/j.ijdrr.2018.02.020.
[27] Hickey, M. (2013) *Meet Amazon Prime Air, A Delivery-By-Aerial-Drone Project*. Available at: https://www.forbes.com/sites/matthickey/2013/12/01/meet-amazon-prime-air-amazons-delivery-by-aerial-drone-project/?sh=6f1fa1b279b2.
[28] Hern, A. (2014) *DHL launches first commercial drone 'parcelcopter' delivery service*. Available at: https://www.theguardian.com/technology/2014/sep/25/german-dhl-launches-first-commercial-drone-delivery-service.
[29] Stewart, J. (2014) *Google tests drone deliveries in Project Wing trials*. Available at: https://www.bbc.com/news/technology-28964260.
[30] Dorling, K. *et al.* (2017) 'Vehicle Routing Problems for Drone Delivery', *IEEE Trans. Syst. Man, Cybern. Syst.*, 47(1), pp. 70–85. doi: 10.1109/TSMC.2016.2582745.
[31] Coliandris, M. (2023) 'Drones as Disruptive Socio-technical Systems: A Case Study of Drone Crime and Control', in Housley, W. et al. (eds) *SAGE Handb. Digit. Soc*. SAGE Publications Ltd. doi: https://doi.org/10.4135/9781529783193.
[32] Carayon, P. (2006) 'Human factors of complex sociotechnical systems', *Appl. Ergon.*, 37(4 SPEC. ISS.), pp. 525–535. doi: 10.1016/j.apergo.2006.04.011.
[33] Walker, G. H. *et al.* (2008) 'A review of sociotechnical systems theory: A classic concept for new command and control paradigms', *Theor. Issues Ergon. Sci.*, 9(6), pp. 479–499. doi: 10.1080/14639220701635470.
[34] Davis, M. C. *et al.* (2014) 'Advancing socio-technical systems thinking: A call for bravery', *Appl. Ergon.*, 45(2 Part A), pp. 171–180. doi: 10.1016/j.apergo.2013.02.009.
[35] Stornelli, A., Ozcan, S. and Simms, C. (2021) 'Advanced manufacturing technology adoption and innovation: A systematic literature review on barriers, enablers, and innovation types', *Res. Policy*, 50(6), p. 104229. doi: 10.1016/j.respol.2021.104229.
[36] Challenger, R., Clegg, C. W. and Robinson, M. A. (2010) *Understanding Crowd Behaviours. In: Practical Guidance and Lessons Identified*, *TSO*. London: The Stationary Office.
[37] Sabino, H. *et al.* (2022) 'A systematic literature review on the main factors for public acceptance of drones', *Technol. Soc.*, 71(July), p. 102097. doi: 10.1016/j.techsoc.2022.102097.
[38] Mohammad, W. A. M. *et al.* (2023) 'Innovative solutions in last mile delivery: concepts, practices, challenges, and future directions', *Supply Chain Forum*, 24(2), pp. 151–169. doi: 10.1080/16258312.2023.2173488.
[39] Aurambout, J. P., Gkoumas, K. and Ciuffo, B. (2022) 'A drone hop from the local shop? Where could drone delivery as a service happen in Europe and the USA, and how many people could benefit from it?', *Transp. Res. Interdiscip. Perspect.*, 16(December), p. 100708. doi: 10.1016/j.trip.2022.100708.
[40] Hwang, J. and Kim, J. J. (2021) 'Expected benefits with using drone food delivery services: its impacts on attitude and behavioral intentions', *J. Hosp. Tour. Technol.*, 12(3), pp. 593–606. doi: 10.1108/JHTT-05-2020-0123.
[41] EASA (2021) *Study on the societal acceptance of urban air mobility in Europe*. Available at: https://www.easa.europa.eu/full-report-study-societal-acceptance-urban-air-mobility-europe.
[42] Perussi, J. B., Gressler, F. and Seleme, R. (2019) 'Supply chain 4.0: Autonomous vehicles and equipment to meet demand', *Int. J. Supply Chain Manag.*, 8(4), pp. 33–41.
[43] Sah, B., Gupta, R. and Bani-Hani, D. (2021) 'Analysis of barriers to implement drone logistics', *Int. J. Logist. Res. Appl.*, 24(6), pp. 531–550. doi: 10.1080/13675567.2020.1782862.
[44] Raj, A. and Sah, B. (2019) 'Analyzing critical success factors for implementation of drones in the logistics sector using grey-DEMATEL based approach', *Comput. Ind. Eng.*, 138(August), p. 106118. doi: 10.1016/j.cie.2019.106118.
[45] Zhang, Y. and Kamargianni, M. (2022) 'A review on the factors influencing the adoption of new mobility technologies and services: autonomous vehicle, drone, micromobility and mobility as a service', *Transp. Rev.* doi: 10.1080/01441647.2022.2119297.