BER ISSN: 2619-9491 BUSINESS AND ECONOMICS RESEARCH JOURNAL www.berjournal.com

Business and Economics Research Journal Vol. 14, No.2, 2023 pp. 227-242 doi: 10.20409/berj.2023.413

Analyzing the Challenges to Adoption of Drones in the Logistics Sector Using the Best-Worst Method

Sinan Çıkmak[1], **Gökhan Kırbaç**[2], **Buşra Kesici**[3]

Abstract: *Drones, which are unmanned aerial vehicles, are used in various areas. Some important worldwide companies have been interested to integrate drone technology into their logistics applications. Although the use of drones promises various advantages such as reducing costs and improving responsiveness in the logistics sector, there are also various challenges to the adoption of this technology. Therefore, this study aims to identify and prioritize the challenges to drone technology adoption in the logistics sector. Initially, 34 challenges under seven major dimensions for the study were identified by a thorough literature review and consultation with selected experts. Then, the best-worst method (BWM) is applied to rank these major challenges and associated sub-criteria. The results show that "terrorist attacks", "lack of legal regulations", "difficulty of flight permit processes", "flight area limitation due to restrictive visual line of sight (VLOS)", and "personal data protection" are the top five challenges that confront the logistics sector for adopting drone technology. The findings of this research will provide important insights to practitioners and researchers interested in new technologies that can be applied in the logistics sector.*

Keywords: Drones, Logistics, Unmanned Aerial Vehicle, Challenge Analysis, Best-Worst Method

JEL: L93, O33, Q55

Received : 14 December 2022
Revised : 25 February 2023
Accepted : 16 March 2023

Type : Research

1. Introduction

A drone is a small aircraft that can fly without a human pilot, usually made of lightweight materials, that can be remotely controlled or fly autonomously (Hayhurst, Maddalon, Miner, DeWalt, & McCormick, 2006; Agatz, Bouman, & Schmidt, 2018). There are different terms used for drones, such as a remotely piloted aircraft (RPA), an unmanned aerial vehicle (UAV), and an unmanned aircraft system (UAS). In this study, the term "drone" was used as it is generally preferred in the literature (Ferrandez, Harbison, Weber, Sturges, & Rich, 2016; Agatz et al., 2018; Sah, Gupta, & Bani-Hani, 2021).

Drones initially began to be used in military operations (Raj & Sah, 2019). With the latest technological advancement, drones have started to be used in a wide variety of fields such as package deliveries (Moshref-Javadi & Winkenbach, 2021), humanitarian relief operations (Sandvik & Lohne, 2014), agriculture (Malveaux, Hall, & Price, 2014), healthcare services (Haidari et al., 2016), civil and construction applications (Bogue, 2018), entertainment/media (Guerriero, Surace, Loscrí, & Natalizio, 2014), public safety and security (He, Chan, & Guizani, 2017), and mining (Lee & Choi, 2016). The commercialization of drones

Cite this article as: Çıkmak, S., Kırbaç, G., & Kesici, B. (2023). Analyzing the challenges to adoption of drones in the logistics sector using the best-worst method. *Business and Economics Research Journal,* 14(2), 227-242. http://dx.doi.org/10.20409/berj.2023.413

The current issue and archive of this Journal is available at: ***www.berjournal.com***

[1] PhD., Lecturer, Duzce University, Social Sciences Vocational School, Business Administration Program, Duzce, Turkiye, sinancikmak@duzce.edu.tr (Corresponding Author)
[2] PhD., Lecturer, Istanbul Kultur University, Vocational School, Istanbul, Turkiye, g.kirbac@iku.edu.tr
[3] PhD., Lecturer, Duzce University, Social Sciences Vocational School, Business Administration Program, Duzce, Turkiye, busrakesici@duzce.edu.tr

will have a significant impact on many sectors such as e-commerce, search and relief operations, healthcare supply chains. Especially, drones are considered to have the potential to change the logistics industry (Raj & Sah, 2019). Compared to traditional transportation activities, drones have several advantages such as a constant and high travel speed, no need for physical road infrastructure, a decrease in the distance between two points, and no traffic jams (Moshref-Javadi & Winkenbach, 2021). The use of drones eliminates the delays caused by road transportation, especially for short-term deliveries, as it takes transportation to the sky. Compared to truck delivery, the operational cost of drone delivery is quite low (Raj & Sah, 2019). Drones are considered the transportation mode of the future for various applications in the logistics industry (Moshref-Javadi & Winkenbach, 2021). Global companies such as Google, Amazon, FedEx, UPS, DHL, Alibaba, and Matternet have shown interest in using drones for last-mile delivery which is an important part of the logistics operations (Chung, Sah, & Lee, 2020). These leading industry players continue to work on developing and testing drone delivery models (Moshref-Javadi & Winkenbach, 2021). Drones are an innovative method to increase responsiveness and efficiency in the logistics sector (Sah et al., 2021). To a recent report, it is estimated that the drone logistics and transportation market will reach USD 11.20 billion in 2022, increasing to USD 29.06 billion by 2027, reaching a compound annual growth rate (CAGR) of 21.01% (MarketsandMarkets, 2018).

Interest in the use of drones in logistics among academics and practitioners is growing exponentially due to its advantages (Clarke, 2014). Academic research is conducted examining various aspects of drone-based logistics systems (Moshref-Javadi & Winkenbach, 2021). Industry and academia are researching to make drone delivery a commercial success (Agatz et al., 2018). The high maneuverability of drones can optimize various logistics activities such as warehousing, inventory management, transportation, and route planning and minimize supply chain costs (Rejeb, Rejeb, Simske, & Treiblmaier, 2021). Although drones provide advantages such as cost reduction and efficiency in logistics, they still have many problems to be solved in the implementation phase. Various challenges including government regulations, safety, environmental, technical, and economic issues make the future of drone logistics uncertain (Sah et al., 2021). Identifying and prioritizing obstacles related to drone logistics plays a critical role in its adoption by companies. This study proposes the following research objectives to guide practitioners and policymakers in the adoption of drone logistics: (a) To identify the challenges to drone adoption in the logistics sector, (b) To rank the major challenges and sub-criteria to drone adoption in the logistics sector.

Firstly, we conducted an extensive literature review on drone logistics to address the above research objectives. After determining the drone logistics challenges in the literature, the major challenges and sub-criteria to be analyzed were defined based on expert opinions. Then, we determined the importance weights of the challenges in drone logistics using the best-worst method (BWM), which is a current multi-criteria decision-making method. The use of drones in logistics is a new technological application, so examining the challenges affecting the adoption of drone logistics presents important insights to researchers and practitioners in the logistics sector (Sah et al., 2021). In addition, the number of studies analyzing the challenges to the adoption of drone logistics is insufficient. This is the first study that identifies and ranks the challenges to drone adoption in the logistics sector by applying the BWM. The remainder of this paper is structured as follows: A literature review is conducted in section 2. Section 3 presents the research methodology, followed by the application of the framework in section 4. Section 5 presents the results and discussion. The managerial implications are discussed in section 6. Finally, the conclusion and limitations and future research suggestions are presented in section 7.

2. Literature Review

Unmanned aerial systems have gained popularity in recent years for both business and personal use. The adoption of drone delivery in the logistics sector may be used by a number of significant aspects. Drones have a variety of additional uses nowadays, despite the fact that they were primarily developed for military operations because to the risks and dangers for personnel in manned aircraft (Springer, 2013). Applications for the primary barriers to drone adoption in the logistics industry are shown in this paper, along with a rating of the minor barriers. The national and international literature was reviewed in the context of the study, and an attempt was made to identify the fields where the use of drones is widespread.

Drones are used in a wide variety of sectors and fields. They are utilized for oil and gas pipeline monitoring and aerial inspection in addition to product delivery (Rathlev, Meyer, & Juerss, 2012). The usage of commercial drones in the context of governance, ethics, and privacy has been the subject of a techno ethical assessment (Luppicini & So, 2016). Other uses include surveying for mountain rescue situations (Silvagni, Tonoli, Zenerino, & Chiaberge, 2017) and gathering geographical data including ethics of drones (Coeckelbergh, 2013). Otto et al. (2018) have reviewed the literature on optimization techniques for drone use in civil areas. Additionally, drones have been used in civil and construction applications in order to monitor operations of infrastructure systems (Ham, Han, Lin, & Golparvar-Fard, 2016; Bogue, 2018), healthcare applications (Emery, 2016; Kim, Lim, Cho, & Côté, 2017; Ghelichi, Gentili, & Mirchandani, 2021; Nyaaba & Ayamga, 2021), agriculture applications (Malveaux et al., 2014; Stehr, 2015; Akkamış & Çalışkan, 2020; Özgüven, Altaş, Güven, & Çam, 2022), public safety and security (Vattapparamban, Güvenç, Yurekli, Akkaya, & Uluağaç, 2016; He et al., 2017), mining (Lee & Choi, 2016); imaging (Marris, 2013).

Surveying and mapping have both been successfully completed using drones. Hallermann and Morgenthal (2013) have proven that drones equipped with high-resolution picture and video cameras used for extensive visual inspection and damage detection of huge structures are both successful and cost-efficient. Drones have been utilized (Casella et al., 2017) to map coral reefs using motion photogrammetry methods. According to Kwon, Kim, and Park (2017), the adoption of drone technology into our daily lives may have a negative impact on the economy, institutional issues, health and social well-being, and living conditions. Yoo et al. (2018) employed a survey-based approach to investigate numerous aspects affecting the public's attitude and intention to adopt drone delivery. According to Liu et al. (2018), the use of drones has increased due to their cheaper cost in product delivery operations, however this efficiency disappears in the event of infrequent demand. The study concentrated on this issue and investigated a tandem steering approach to the drone and truck routing issue. Boysen et al. (2018) used mixed integer programming to research drone programming on a specific truck route. According to Raj and Sah (2019), the usage of drones has the potential to decrease delivery times by avoiding traffic bottlenecks, and it has a negative impact on carbon emissions when compared to conventional transportation modes. Chung et al. (2020) has investigated of drone processes according to the issues of, agriculture, construction, media, transportation, security etc. Kellermann, Biehle, and Fischer (2020) have found that technical and legal obstacles prevent drones from being used for package and passenger transport. In addition, it found that the most frequently cited transport-related promises, such as less traffic, shorter travel times, and environmental conditions, need to be substantiated by scientific data. Once more in the area of product delivery, Moshref-Javadi et al. (2021) conducted a comparison of the vehicle and drone delivery models. The return of the drones launched for package delivery from trucks will be timed and routed in accordance with the vehicle using a mathematical model. Osakwe et al. (2022) conducted a social and cognitive study to determine whether end customers in the future will accept the usage of drones in delivery procedures.

Researchers (Emery, 2016; Kim et al., 2017; Scott & Scott, 2017; Ghelichi et al., 2021; Nyaaba & Ayamga, 2021) have all conducted studies on the usage of drones in the fields of humanitarian relief and health. Emery (2016) has stated that drones have a more helpful side as technology and innovation improve. Drones may one day be used to transfer organs around the world (Francisco, 2016). Scott and Scott (2017) presented drone delivery models expressly for the healthcare industry. Drones' use in the distribution and collection of test kits and medicines for patients with chronic conditions was considered (Kim et al., 2017). Nyaaba and Ayamga (2021) discussed a literature review that looked at the challenges of successfully using medical drones as well as their potential advantages while transporting different medical supplies. Ghelichi et al. (2021) have been optimized a drone fleet's logistics and routes for the prompt delivery of medical supplies.

In some studies (Malveaux et al., 2014; Stehr, 2015; Akkamış & Çalışkan, 2020; Özgüven et al., 2022) drones used in agriculture were reviewed. According to Malveaux et al. (2014), drones can scan enormous expanses of land without the significant costs and inherent safety issues associated with using much bigger manned aircraft. Drone use can give real-time pictures and sensor data from farm field locations that are difficult to reach rapidly by foot or car. It can be challenging to swiftly access centrally situated crops by foot or by land vehicle without causing damage to part of the crops when dense or very tall rows of crops are present. Stehr (2015) illustrated how drones can be used in agriculture and made the argument that because they are not cloud-blocked, drones may be more effective than satellites. UAV use in agriculture has been found to be a quicker, cheaper and more cost-effective remote sensing technology than other systems (Akkamış & Çalışkan, 2020). Although the agricultural industry benefits greatly from the creation of new applications, it is anticipated that drone technology will be extensively utilized in this industry in the years to follow (Özgüven et al., 2022).

UAV studies in the areas of logistics and supply chain are rare, according to domestic literature. According to Anbaroğlu (2017), in the subsequent decades, parcel delivery in urban areas would be accomplished by UAS. In the area of transportation, Nakıboğlu (2020) conducted research on drone transportation and its application in last-mile deliveries. Results show that the employment of drone technology for the last delivery step will have a positive impact on the environment, time, and money. The objective of Düzgün (2021)'s study has been to assess the degree of influence by examining how drone technology will affect the logistics sector both now and in the future. The growth in the company's market share was the factor that had the biggest influence, whereas security issues had the least impact. The study's findings demonstrate that drone technology will play a significant role in the logistics industry in the future. Çelik and Aydın (2021) have made a convincing case for why consumers might employ drone delivery services for retail goods. Turğut and Şeker (2022 were reviewed the usage of drone transportation in logistics organizations, as well as their applications. The study found that although though drone transportation is a relatively new procedure, its application in logistics businesses and operations has grown quickly and will become more significant in the near future. The only study on this topic, according to Çalışkan and Erturgut (2022), focused on UAV pilots and the employment of UAVs in the logistics industry. The study attempted to ascertain the perception of UAV pilots as well as the demographic factors. The attitudes of drone pilots among industry professionals have changed as a result of the deployment of UAV in the logistics industry.

A number of authors have put up solutions to various drone delivery-related problems. Barmpounakis et al. (2016) commented about the uses and difficulties of drone technology and implementation to transportation and traffic engineering. The effectiveness of a stand-alone drone or truck vs a drone-truck delivery system was examined (Ferrandez et al., 2016). According to the results, unmanned aerial vehicles save time and energy when used with trucks. As the previous Vehicle Routing Problems (VRPs) might not be appropriate to drone delivery due to circumstances like repeated trips to a depot and the effects of battery limit and payload capacity, Dorling et al. (2017) devised a VRP formulation specifically for drone delivery. Sanjab, Saad & Basar (2017) identified the cyber-physical security problems for drone delivery, formulating a zero-sum game between the vendor making the delivery and a hacker attempting to thwart it through cyber or physical attacks. Due to their status as aircraft vehicles, drones might potentially endanger people, property, wildlife, the environment, and other living things. Their shortcomings include privacy concerns. Since its introduction to the public, drones have raised questions about people's safety and privacy (Luppicini & So, 2016). Another negative aspect is the potential for psychological harm due to data security issues in some individuals (Sandbrook, 2015). The researcher's conclusion is that more research is needed to determine whether the highlighted societal dangers of drone use actually exist and how to manage them. Self-regulation of drone use is also needed to assure moral behavior and reduce the possibility of unexpected consequences. When the customer is far from the servicing depot, drones produce more CO_2 emissions than vehicles, according to Goodchild and Toy (2018) analysis of the environmental effects of CO_2 emissions. The aforementioned issues prevent drones from being successfully implemented in the logistics industry. In order to overcome the limiting flight distance of drones, Carlsson and Song (2018) presented a delivery system in which the drone serves consumers while making return trips to a moving vehicle, indicating an increased effectiveness of drone-truck combinations. The negative impacts of the quick uptake of drone use and the unregulated expansion of drone fleets were explored (Merkert & Bushell, 2020) and the significance of regulatory regulations on this matter was underlined. Threats and opportunities are also considered in order to guarantee the controlled expansion of drone use in the future with in the subjects of airports and emergency services. The advantages of using UAV in logistics activities, according to Rejeb et al. (2021), have included assisting human logistics, reducing delivery times and costs, increasing sustainability, and improving flexibility. They also have identified technical, organizational, security-related, and regulatory issues as the challenges brought on by drones. Sah et al. (2021) stated the potential barriers of using the drones.

Given that drone delivery is a novel technology, it is crucial to examine the obstacles in drone logistics in order to give academics and practitioners essential information. This paper offers a framework for using the best- worst method (BWM), a popular multi-criteria decision-making technique, to analyze the implementation barriers for drone logistics. Researchers and practitioners in the logistics industry can learn a lot from the difficulties associated with the adoption of drone logistics. Additionally, this is the first study to use the BWM to describe and rank the barriers to drone adoption in the logistics industry.

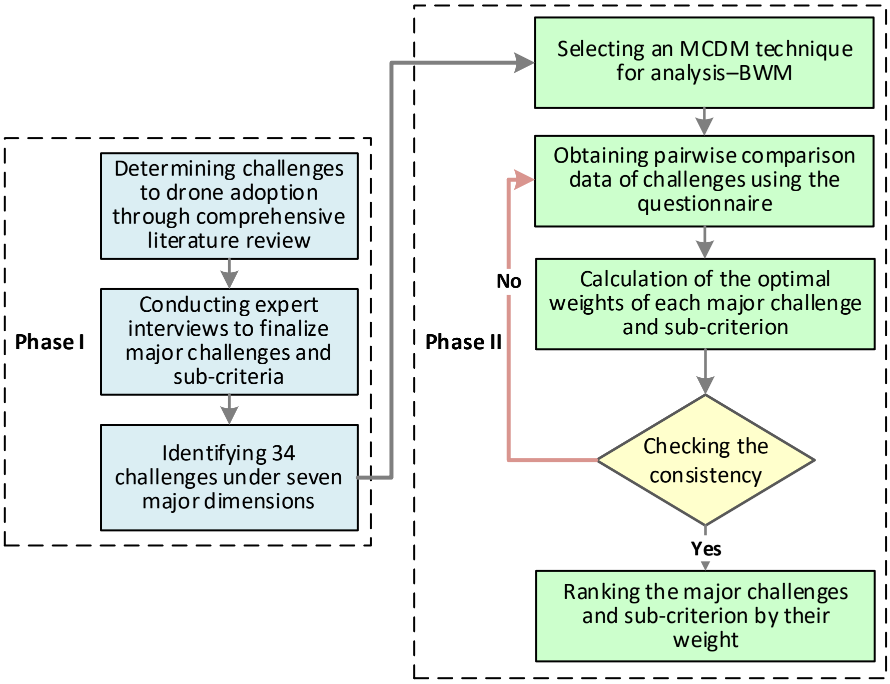
3. Research Methodology

The framework of the research was briefly explained in this section. Then, the steps of the method used in the study are described in detail.

3.1. Research Framework

The study is included two essential phases. In the first phase, challenges to drone adoption in the logistics sector have been determined through an extensive literature review and expert interview. In the second phase, the identified major challenges and their sub-criteria are evaluated and ranked using the BWM. The proposed research framework is represented in Figure 1.

Figure 1. Proposed Research Framework for Analyzing the Challenges to Adoption of Drones in the Logistics Sector



3.2. Best-Worst Method

The best-worst method was firstly proposed by (Rezaei, 2015) as a new multi-criteria decision-making (MCDM) method. Compared to similar methods, this method requires less pairwise comparison data and provides more consistent results than those of the other MCDM methods, which use a full pairwise comparison matrix such as analytical hierarchy process (AHP) (Rezaei, 2015; Badri Ahmadi, Kusi-Sarpong, &

Rezaei, 2017; Aşan & Ayçin, 2020; Wankhede & Vinodh, 2021). The AHP needs to have n(n-1)/2 pairwise comparison, while the BWM method only needs 2n-3 pairwise comparison. This feature of the BWM makes it a more efficient method compared to AHP. In the BWM, firstly, selecting the best and worst criteria and then all other criteria are compared with these two criteria. This structure provides decision makers to perform more reliable pairwise comparisons. Furthermore, only integers are used in pairwise comparisons in the BWM. This prevents a fundamental distance problem associated with the use of fractions (Rezaei, 2015; Mohammadi & Rezaei, 2020). The method has also been applied in previous studies including, but not limited to, supplier selection (Gupta & Barua, 2017), ranking of sustainable innovation criteria (Kusi-Sarpong, Gupta, & Sarkis, 2019), prioritization of sustainable supply chain innovation barriers (Gupta, Kusi-Sarpong, & Rezaei, 2020), analysis of industry 4.0 challenges (Wankhede & Vinodh, 2021), personnel selection process (Arsu & Uğuz Arsu, 2021), prioritization of occupational safety risk factors (Karakurt, Hekimoglu, & Guneri, 2021), evaluation of manufacturing performance (Khan, Kusi-Sarpong, Naim, Ahmadi, & Oyedijo, 2021).

In this study, the BWM approach has been adopted to rank challenges in drone logistics due to the aforementioned advantages. The BWM steps is structured as follows (Rezaei, 2015, 2016):

Step 1. Identify a set of decision criteria. In the first step, a set of criteria $C = \{c_1, c_2, \dots, c_n\}$ is determined related to the defined goal.

Step 2. Selection of the best (e.g., most desirable, most important) and the worst (e.g., least desirable, least important) criteria. In the second step, the decision-maker(s)/expert(s) selects the best and the worst from the criteria set C identified in the first step. No pairwise comparisons are conducted at this step.

Step 3. Determine the preference of the best criterion (c_B) over all the other criteria, using a number between 1 and 9 (numbers between 1 and 9; 1: c_B is equally important to c_j; 9: c_B is extremely more important than c_j). The result of this step is the vector of Best-to-Others (BO) which would be:

$$A_B = (a_{B1}, a_{B2}, \dots, a_{Bn}), \tag{1}$$

where a_{Bj} indicates the preference of the best criterion (c_B) over criterion $c_j \epsilon\ C$ and $a_{BB} = 1$

Step 4. Determine the preference of all the criteria over the worst criterion (c_W), using a number between 1 and 9 (numbers between 1 and 9; 1: c_j is equally important to c_W; 9: c_j is extremely more important than c_W). The resulting Others-to-Worst (OW) vector would be:

$$A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T, \tag{2}$$

where a_{Wj} indicates the preference of the criterion $c_j \epsilon\ C$ over the worst criterion (c_W) and $a_{WW} = 1$

Step 5. Calculation of optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$. To compute the optimal weights for the criteria such that the maximum absolute differences $|\frac{w_B}{w_j} - a_{Bj}|$ and $|\frac{w_j}{w_W} - a_{jW}|$ for all j is minimized, which is formulated to the following minmax model:

$$\min_{w} \max_{j} \left\{ \left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_W} - a_{jW}\right| \right\} \quad s.t. \sum_{j=1}^{n} w_j = 1, \quad w_j \geq 0 \quad \forall j = 1,2,\dots,n. \tag{3}$$

The above model can be calculated by converting it into the following linear problem:

$$
\begin{aligned}
&\min \xi \\
&\text{s.t.} \\
&\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \xi, \qquad \forall \mathrm{j} = 1,2,\dots,\mathrm{n} \\
&\left|\frac{w_j}{w_W} - a_{jW}\right| \leq \xi, \qquad \forall \mathrm{j} = 1,2,\dots,\mathrm{n} \\
&\sum_j w_j = 1 \\
&w_j \geq 0, \qquad \forall \mathrm{j} = 1,2,\dots,\mathrm{n}
\end{aligned} \tag{4}
$$

Solving problem (4), the optimal weights $(w_1^*, w_2^*, \dots, w_n^*)$ and ξ^* are obtained. The value of ξ^* the consistency index (CI) (see Table 1) is used to calculate the consistency ratio (CR), as follows:

$$CR = \frac{\xi^*}{CI} \tag{5}$$

The value of $CR \in [0, 1]$, close to zero is show a high level of consistency of the pairwise comparisons provided by the decision-maker(s)/expert(s). Table 1 shows the maximum values of ξ (consistency index) for different values of a_{BW}.

Table 1. Consistency Index (CI) Table

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index ($max\xi$)	0.00	0.44	1.00	1.63	2.30	3.00	3.73	4.47	5.23

Source: Rezaei (2015)

4. Application of the Framework

To achieve research objectives, a comprehensive literature review was conducted to ascertain the possible challenges to adopting drone technology in the logistics sector. The search was conducted using the Scopus, Web of Science and Ulakbim databases with the keywords "drone logistics" AND "barriers" OR "challenges". In addition, the snowball technique was employed to find other papers that could not be reached by the search results. After that, the determined challenges from the literature review were discussed with two experts, one practitioner (commercial drone trainer) and the other academician. The experts were asked to review the challenges and modify or remove existing ones or suggest more. The challenges list of the adoption of drones in the logistics sector has been identified after more than 1 hour of an interview with each of the two experts on the subject of the study. At the end of the first phase, a total of 34 challenges were finalized and categorized these challenges into seven major dimensions. Table 2 shows the identified major challenges and sub-criteria with their references.

Table 2. Challenges to the Adoption of Drones in Logistics

Major challenge	Sub-criteria	Supporting Literature
Technical (TEC)	Limited payload capacity (TEC1)	Agatz et al., (2018), Moshref-Javadi and Winkenbach, (2021)
	Sensitive to adverse weather conditions (TEC2)	Sah et al., (2021), Rejeb et al., (2021)
	Data communication problems (TEC3)	Expert Opinion
	Risk of malfunction (TEC4)	Yoo et al., (2018), Raj and Sah, (2019)
	Shorter flight time and range due to limited battery capacity (TEC5)	Raj and Sah, (2019), Benarbia and Kyamakya, (2021)
	Autonomous flight deficiencies (TEC6)	Benarbia and Kyamakya, (2021)

Table 2. Challenges to the Adoption of Drones in Logistics (Continued)

Major challenge	Sub-criteria	Supporting Literature
Regulations (REG)	Lack of legal regulations (REG1)	Rejeb et al., (2021), Benarbia and Kyamakya, (2021)
	Pilot certification and training deficiencies (REG2)	Sah et al., (2021)
	Restriction of permitted flight area (REG3)	Kamat et al., (2022)
	Difficulty of flight permit processes (REG4)	Expert Opinion
	Deficiencies in insurance obligations (REG5)	Sah et al., (2021), Kamat et al., (2022)
	Flight area limitation due to restrictive visual line of sight (VLOS) (REG6)	Kamat et al., (2022)
Organizational (ORG)	Costly investment requirement for infrastructure (ORG1)	Raj and Sah, (2019), Rejeb et al., (2021)
	Inadequate organizational capabilities, skills, and experience with drones (ORG2)	Rejeb et al., (2021)
	Lack of skilled workforce (ORG3)	Raj and Sah, (2019), Kamat et al., (2022)
	Difficulty in controlling complex drone delivery system (ORG4)	Benarbia and Kyamakya, (2021)
	Deployment of recharging stations (ORG5)	Huang and Savkin, (2020), Benarbia and Kyamakya, (2021)
Safety (SF)	Risk of operational accidents (SF1)	Kellermann et al., (2020), Rejeb et al., (2021)
	Airspace safety (SF2)	Kwon et al., (2017), Chung et al., (2020)
	Property damage (SF3)	Kwon et al., (2017), Yoo et al., (2018)
	Pilot errors (SF4)	Expert Opinion
	Serious injuries (SF5)	Kwon et al., (2017), Sah et al., (2021)
	Threatening wildlife (especially birds) (SF6)	Chung et al., (2020), Rejeb et al., (2021)
Privacy (PRV)	Personal data protection (PRV1)	Expert Opinion
	Violation of privacy (PRV2)	Kellermann et al., (2020)
	Mass data collection (PRV3)	Chung et al., (2020)
Security (SEC)	Cyber-attacks (SEC1)	Chung et al., (2020), Sah et al., (2021)
	Terrorist attacks (SEC2)	Kellermann et al., (2020), Rejeb et al., (2021)
	Unauthorized drones (SEC3)	Anbaroğlu, (2017), Chung et al., (2020)
	Physical attacks on drones (SEC4)	Sah et al., (2021)
	Data security (SEC5)	Akram et al., (2017), Chung et al., (2020)
Socio-economic (SOC)	Unemployment (SOC1)	Kwon et al., (2017), Sah et al., (2021)
	Public perception and acceptance (SOC2)	Anbaroğlu, (2017), Rejeb et al., (2021)
	Societal anxiety about automation (SOC3)	Raj and Sah, (2019)

The identified challenges were evaluated and ranked using BWM in the second phase. For this, the five experts were chosen from the area related to the research topic for obtaining reliable data. Among the five experts, three members from the industry and the remaining two are academicians. All industry experts are specialized in the logistics sector. In addition, these industry experts are closely related to current logistics technologies. The academic experts are actively researching the logistics domain and drone technology. Data were collected using questionnaires presented to the experts. The questionnaire was designed so that experts can perform pairwise comparisons of the challenges. In addition, the scoring system of the BMW method was explained to the experts. The data obtained from experts' questionnaire forms were analyzed using the BWM.

As explained in the steps of the BMW method, each expert was requested to choose the best and worst challenges among the major challenge and sub-criteria. Further, they were asked to assess best-to-others and others-to-worst for all the major and sub-category challenges respectively using a 1–9 scale. Table 3 displays the pairwise comparison of major category challenges for all five experts.

Table 3. Pairwise Comparison for Major Challenges

Experts	The most important major challenge	Best-to-Others vectors for 5 experts						
		TEC	REG	ORG	SF	PRV	SEC	SOC
Ex.1	REG	7	1	6	2	3	3	6
Ex.2	REG	7	1	7	2	3	3	4
Ex.3	ORG	2	2	1	4	6	5	4
Ex.4	SEC	2	2	7	8	8	1	3
Ex.5	SEC	4	2	6	4	4	1	6

	Others-to-Worst vectors for 5 experts				
Experts →	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5
The least important major challenge →	TEC	ORG	PRV	PRV	SOC
TEC	1	3	5	6	2
REG	7	8	6	5	5
ORG	3	1	7	4	2
SF	5	7	6	4	3
PRV	4	5	1	1	2
SEC	3	5	5	8	5
SOC	2	6	6	3	1

After obtaining pairwise comparisons of all challenges, the weights of major category and sub-category challenges were calculated using Equation (3) and (4). The local weights of each major challenge and sub-criteria were obtained by averaging the weights obtained from each expert. The weights of major challenges are shown in Table 4. Furthermore, the consistency of all computed weights was checked using Equation (5).

Table 4. Local Weights of Major Challenges

Major Challenges	Major Challenges Weights					
	Ex.1	Ex.2	Ex.3	Ex.4	Ex.5	Average
Technical (TEC)	0.0417	0.0592	0.1974	0.2007	0.1049	0.12075
Regulations (REG)	0.3490	0.3215	0.1974	0.2007	0.2098	0.25565
Organizational (ORG)	0.0677	0.0327	0.2961	0.0573	0.0699	0.10474
Safety (SF)	0.2031	0.2071	0.0987	0.0502	0.1049	0.13279
Privacy (PRV)	0.1354	0.1380	0.0329	0.0314	0.1049	0.08852
Security (SEC)	0.1354	0.1380	0.0789	0.3261	0.3497	0.20562
Socio-economic (SOC)	0.0677	0.1035	0.0987	0.1338	0.0559	0.09193

Finally, the global weights for each sub-criterion are calculated by multiplying the major challenge weight by the respective sub-challenge local weight. The local and global weights as well as the ranking of major challenges and their sub-barriers are illustrated in Table 5.

Table 5. Weights and Rankings of Major Challenges and Sub-criteria

Major Challenges	Major Challenges Weights	Major Challenges Rank	Sub-criteria	Sub-criteria Local Weights	Sub-criteria Local Rank	Sub-criteria Global Weight	Global Rank
Technical (TEC)	0.12075	4	TEC1	0.1038	6	0.0125	32
			TEC2	0.2865	1	0.0346	12
			TEC3	0.1823	2	0.0220	23
			TEC4	0.1199	5	0.0145	28
			TEC5	0.1433	4	0.0173	26
			TEC6	0.1641	3	0.0198	25
Regulations (REG)	0.25565	1	REG1	0.2641	1	0.0675	2
			REG2	0.1657	4	0.0424	6
			REG3	0.0922	6	0.0236	20
			REG4	0.2011	2	0.0514	3
			REG5	0.1062	5	0.0271	17
			REG6	0.1707	3	0.0436	4
Organizational (ORG)	0.10474	5	ORG1	0.3666	1	0.0384	9
			ORG2	0.2136	2	0.0224	22
			ORG3	0.2102	3	0.0220	24
			ORG4	0.1280	4	0.0134	30
			ORG5	0.0817	5	0.0086	34
Safety (SF)	0.13279	3	SF1	0.2242	2	0.0298	16
			SF2	0.3049	1	0.0405	7
			SF3	0.1233	4	0.0164	27
			SF4	0.1687	3	0.0224	21
			SF5	0.1082	5	0.0144	29
			SF6	0.0706	6	0.0094	33
Privacy (PRV)	0.08852	7	PRV1	0.4901	1	0.0434	5
			PRV2	0.3613	2	0.0320	15
			PRV3	0.1486	3	0.0132	31
Security (SEC)	0.20562	2	SEC1	0.1899	2	0.0391	8
			SEC2	0.3388	1	0.0697	1
			SEC3	0.1717	4	0.0353	11
			SEC4	0.1185	5	0.0244	19
			SEC5	0.1810	3	0.0372	10
Socio-economic (SOC)	0.09193	6	SOC1	0.3602	2	0.0331	14
			SOC2	0.2656	3	0.0244	18
			SOC3	0.3742	1	0.0344	13

5. Results and Discussion

Within the scope of the study, the challenges encountered in the use of drones in the logistics sector are discussed. First, in order to determine these challenges, an in-depth literature review was made and several expert opinions were used. Then, these challenges were divided into seven major categories and a total of 34 sub-challenges were reached. Finally, BWM was applied to rank these seven major categories and 34 sub-challenges. The findings obtained from the analysis list the major categories of challenges from the best to the worst as follows: Regulations (REG), Security (SEC), Safety (SF), Technical (TEC), Organizational (ORG), Socio-Economic (SOC) and Privacy (PRV). The results show that the biggest challenges to the application of drones in the logistics sector are the regulatory issues. In addition, these regulatory deficiencies vary from country to country (Dorling et al., 2017). The rapid completion of current deficiencies in regulations will pave the way for realistic applications and processes related to drone logistics.

Among the main challenges, the second and third weighted challenges are security and safety. In fact, these challenges reveal the concerns of the parties that will benefit from drones in the logistics sector and the parties that will use the drone physically (Otto et al., 2018). It seems difficult that progress can be made without resolving the safety and security issues related to drone logistics. Again, it is seen that the technical and organizational concepts are the challenges with the fourth and fifth weights among the major challenges. It is known that drones have certain technical and mechanical equipment. However, this equipment of drones should be able to respond more clearly to the needs of both the logistics sector and other sectors. At the same time, it is extremely important that all these processes are manageable and controllable from an organizational point of view. Finally, it is seen that Socio-economic and Privacy concepts have the lowest weight among the major challenges. As with any new technology or application, necessary steps and time are needed for the widespread use of drones in the logistics industry (Lidynia, Philipsen, & Ziefle, 2017). It can be said that there is a general acceptance for the use of drones in some areas, but the reflection of this acceptance on the logistics sector will not be easy in the short term.

Findings from the BWM revealed that the highest sub-criteria local weights of the challenges are terrorist attacks (SEC2), lack of legal regulations (REG1), difficulty of flight permit processes (REG4), flight area limitation due to restrictive visual line of sight (VLOS) (REG6) and personal data protection (PRV1). Here, drones may be exposed to some external threats or attacks after a certain location. It seems difficult for now to control such threats. Such situations that may occur during the use of drones in a logistics process will also deeply affect product reliability. On top of these issues, it makes it difficult to control the threats that may arise from the deficiencies in the legal regulations. Legal regulations for the use of drones in the logistics sector need to be determined with clearer lines. In addition, the other issues brought about by the lack of regulation are the challenges experienced with the flight permits of drones and VLOS issues. All these challenges, which are necessary for the realization of healthy flights, need to be resolved by taking into account the workflows and types in the logistics sector. Findings from the BWM revealed that the lowest sub-criteria local weights of the challenges are deployment of recharging stations (ORG5), threatening wildlife (especially birds) (SF6) and limited payload capacity (TEC1).

The results show that the regulation and safety issues of drones are more important than the difficulty of establishing recharging stations for drones, which are among organizational issues. Drones must be charged after a certain use, and this is actually a general issue that needs to be established for drones, so there are more important challenges that prevent this issue. Undoubtedly, the more intensive use of drones in daily life will affect natural life. However, from the point of view of businesses, it can be said that there are clearer conceptual and architectural challenges in front of the use of drones in their current processes.

6. Managerial Implications

The findings of this study ensure logistics managers and experts some significant managerial implications for businesses that want to use drones in their logistics operations and processes. In recent years, businesses have entered into certain researches and steps to ensure effectiveness and efficiency in logistics processes. This study presents the application challenges of drone logistics with a model in order to reveal the research with clearer lines and to provide benefits. In this context, revealing the said challenges related to drone logistics is important for the development of managerial skills in this field. So, this study has the potential to be a roadmap for firms that want to use drones in their logistics operations and processes. Based on the results, the study ensures some managerial implications for the logistics use of drones. These managerial implications are thought to be beneficial for drone logistics adoption.

• Contribution to Third Party Logistics (3PL) Providers and Fourth Party Logistics (4PL) Providers: 3PL and 4PL companies have some major operations like transportation, handling, warehousing and stock management for other firms' logistics and supply chain operations. Therefore, companies that have the potential to use the concept of drone logistics first in their processes are 3PL and 4PL service providers (Moshref-Javadi & Winkenbach, 2021; Sah et al., 2021). This study clearly reveals the challenges that businesses want to use drones in the provision of logistics and supply chain services. By using this data, businesses can take action to take the necessary steps.

• Contribution to policy makers: As revealed by the results of the study, the lack of regulation regarding drone logistics is one of the challenges. Therefore, it is extremely important for policy makers and governments to issue the necessary regulations for the improvement and execution of processes related to drone logistics. In this context, the study has listed the importance weights of the regulation difficulties. In this way, it is thought that it will be beneficial for policy makers to create regulations.

• Contribution to drone developers: This study is a roadmap for companies that develop drones and its technology. In fact, developers can build a technological architecture by focusing on the current implementation challenges of drones.

• Increasing awareness of drone usage for logistics: Undoubtedly, it is difficult for businesses to change their traditional logistics business practices. However, in order to reduce this resistance to the change in drone logistics, companies with global norms should increase the use of drones in their logistics systems. For this reason, it is thought that the study will raise awareness about the use of drones in logistics processes.

7. Conclusion

In recent years, changing customer expectations and increasing competition conditions have made it necessary to develop applications that include modern technologies such as drones in logistics processes, which is one of the most critical stages of supply chains. Drone technology has been a critical stage for businesses to improve their capabilities in different industries and application areas. The rapid increase in e-commerce activities in recent years has created many negative factors in terms of cost and time for delivery companies. Drone technology has the potential to increase the effectiveness of some logistics processes, especially last-mile delivery.

Some companies such as Amazon, DHL, and FedEx have already begun to incorporate drones in delivery of package, cargo. But implementation of drone technology is not easy, and there are challenges and risks to its implementation in logistics activities. Therefore, companies need to identify potential challenges to drone logistics implementation in order to be able to create appropriate solutions to overcome them. Evaluation of the challenges of drone technologies while implementing logistics activities has been the subject of this study.

In the view of this, a thorough literature review has done to find any potential problems that can arise when drone technology is used in the logistics sector. Concerning potential issues that the literature review found, experts have consulted. After conducting a more than hour-long discussion with the pertinent experts, it has identified what challenges can arise when drones are implemented in the logistics industry. At the conclusion of the first phase, 34 issues in all have been identified and divided into seven main categories. The BWM was used to analyze and rank the challenges identified in the second phase of the research. The weights of the main category and sub-category challenges were calculated after getting pairwise comparisons of each challenge.

In summary, looking at the results of the BWM in general, terrorist attacks, lack of legal regulations and difficulty of flight permit processes are the most important challenges. The results show that the most important challenges to the implementation of drone logistics are external attacks and the deficiencies of legal regulations for drone flights. Therefore, it is necessary to provide technical infrastructure and flight arrangements in order to ensure the applicability of drone logistics.

This study also has some limitations. The study was conducted in Turkey, which is in the category of developing countries. Therefore, different results may arise in a developed country with a better technological infrastructure. Another limitation of this study is that it only focuses on challenges; however, future research can investigate the enablers of drone technology implementations into logistical activities. In future studies, other MCDM methods can be used together with the fuzzy sets approach. In addition, a case study can be conducted in a company that is closely interested in drone logistics.

Declarations and Disclosures

Ethical Responsibilities of Authors: The authors of this article confirm that their work complies with the principles of research and publication ethics.

Conflicts of Interest: No potential conflict of interest was reported by the authors.

Funding: The authors received no financial support for the preparation and/or publication of this article.

Author Contributions: The authors confirm contribution to the article as follows: Conceptualization and design, S. Çıkmak; data collection, S. Çıkmak, G. Kırbaç, and B. Kesici; analysis of data and interpretation of results, S. Çıkmak, G. Kırbaç, and B. Kesici; writing the first draft of the manuscript, S. Çıkmak; review and editing, S. Çıkmak. The manuscript/article was read and approved by all the authors, and all authors accepted responsibility for their article.

Plagiarism Checking: This article was screened for potential plagiarism using a plagiarism screening program.

References

Agatz, N., Bouman, P., & Schmidt, M. (2018). Optimization approaches for the traveling salesman problem with drone. *Transportation Science,* 52(4), 965-981.

Akkamış, M., & Çalışkan, S. (2020). İnsansız hava araçları ve tarımsal uygulamalarda kullanımı. *Türkiye İnsansız Hava Araçları Dergisi,* 2(1), 8-16.

Akram, R. N., Markantonakis, K., Mayes, K., Habachi, O., Sauveron, D., Steyven, A., & Chaumette, S. (2017). Security, privacy and safety evaluation of dynamic and static fleets of drones. In 2017 IEEE/AIAA 36th *Digital Avionics Systems Conference (DASC)* (pp. 1-12).

Anbaroğlu, B. (2017). Parcel delivery in an urban environment using unmanned aerial systems: A vision paper. In *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 4*(4W4), (pp.73-79). Karabük: Copernicus GmbH.

Arsu, T., & Uğuz Arsu, Ş. (2021). Personel seçim sürecinde kullanılan kriterlerin best-worst metodu (BWM) ile değerlendirilmesi. *Üçüncü Sektör Sosyal Ekonomi Dergisi,* 56(3), 1949-1967.

Aşan, H., Ayçin, E. (2020). Kurumsal kaynak planlama sistemlerinin seçimindeki kriterlerin best-worst metodu ile değerlendirilmesi. *Akademik İzdüşüm Dergisi,* 5(2), 114-124.

Badri Ahmadi, H., Kusi-Sarpong, S., & Rezaei, J. (2017). Assessing the social sustainability of supply chains using best worst method*. Resources, Conservation and Recycling, 126*, 99-106.

Barmpounakis, E. N., Vlahogianni, E. I., & Golias, J. C. (2016). Unmanned aerial aircraft systems for transportation engineering: Current practice and future challenges. *International Journal of Transportation Science and Technology,* 5(3), 111-122.

Benarbia, T., & Kyamakya, K. (2021). A literature review of drone-based package delivery logistics systems and their implementation feasibility. *Sustainability,* 14(1), 360.

Bogue, R. (2018). What are the prospects for robots in the construction industry? *Industrial Robot: An International Journal,* 45(1), 1-6.

Boysen, N., Briskorn, D., Fedtke, S., & Schwerdfeger, S. (2018). Drone delivery from trucks: Drone scheduling for given truck routes. *Networks,* 72(4), 506-527.

Çalışkan, T. B., & Erturgut, R. (2022). Lojistik faaliyetlerde İHA kullanımı: İHA pilotları üzerinde bir araştırma. *Uygulamalı Bilimler Fakültesi Dergisi,* 4(1), 1-16.

Carlsson, J. G., & Song, S. (2018). Coordinated logistics with a truck and a drone. *Management Science,* 64(9), 4052-4069.

Casella, E., Collin, A., Harris, D., Ferse, S., Bejarano, S., Parravicini, V., … Rovere, A. (2017). Mapping coral reefs using consumer-grade drones and structure from motion photogrammetry techniques. *Coral Reefs,* 36(1), 269-275.

Çelik, Z., & Aydın, İ. (2021). Perakendecilikte drone ile ürün teslimatının tüketicilerin davranışsal niyetlerine etkisi. *Bmij,* 9(4), 1422-1436.

Chung, S. H., Sah, B., & Lee, J. (2020). Optimization for drone and drone-truck combined operations: A review of the state of the art and future directions. *Computers and Operations Research,* 123, 105004.

Clarke, R. (2014). Understanding the drone epidemic. *Computer Law and Security Review,* 30(3), 230-246.

Coeckelbergh, M. (2013). Drones, information technology, and distance: Mapping the moral epistemology of remote fighting. *Ethics and Information Technology,* 15(2), 87-98.

Dorling, K., Heinrichs, J., Messier, G. G., & Magierowski, S. (2017). Vehicle routing problems for drone delivery. *IEEE Transactions on Systems, Man, and Cybernetics: Systems,* 47(1), 70-85.

Düzgün, M. (2021). Investigation of the criteria affecting the decision of use of drone technology in the logistics sector by DEMATEL method*. Journal of Aviation,* 5(2), 249-264.

Emery, J. R. (2016). The Possibilities and pitfalls of humanitarian drones. *Ethics & International Affairs, 30*(2), 153–165.

Ferrandez, S. M., Harbison, T., Weber, T., Sturges, R., & Rich, R. (2016). Optimization of a truck-drone in tandem delivery network using k-means and genetic algorithm. *Journal of Industrial Engineering and Management,* 9(2), 374-388.

Francisco, M. (2016). Organ delivery by 1,000 drones. *Nature Biotechnology,* 34(7), 684-684.

Ghelichi, Z., Gentili, M., & Mirchandani, P. B. (2021). Logistics for a fleet of drones for medical item delivery: A case study for Louisville, KY. *Computers and Operations Research,* 135, 105443.

Goodchild, A., & Toy, J. (2018). Delivery by drone: An evaluation of unmanned aerial vehicle technology in reducing CO2 emissions in the delivery service industry. *Transportation Research Part D: Transport and Environment,* 61, 58-67.

Guerriero, F., Surace, R., Loscrí, V., & Natalizio, E. (2014). A multi-objective approach for unmanned aerial vehicle routing problem with soft time windows constraints. *Applied Mathematical Modelling,* 38(3), 839-852.

Gupta, H., & Barua, M. K. (2017). Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *Journal of Cleaner Production,* 152, 242-258.

Gupta, H., Kusi-Sarpong, S., & Rezaei, J. (2020). Barriers and overcoming strategies to supply chain sustainability innovation. *Resources, Conservation and Recycling,* 161, 104819.

Haidari, L. A., Brown, S. T., Ferguson, M., Bancroft, E., Spiker, M., Wilcox, A., … Lee, B. Y. (2016). The economic and operational value of using drones to transport vaccines. *Vaccine,* 34(34), 4062-4067.

Hallermann, N., & Morgenthal, G. (2013). Unmanned aerial vehicles (UAV) for the assessment of existing structures. In *IABSE Symposium Report* (Vol. 101, No. 14, pp. 1-8). International Association for Bridge and Structural Engineering.

Ham, Y., Han, K. K., Lin, J. J., & Golparvar-Fard, M. (2016). Visual monitoring of civil infrastructure systems via camera-equipped Unmanned Aerial Vehicles (UAVs): A review of related works. *Visualization in Engineering,* 4(1), 1-8.

Hayhurst, K., Maddalon, J., Miner, P., DeWalt, M., & McCormick, G. (2006). Unmanned aircraft hazards and their implications for regulation. In *2006 IEEE/AIAA 25th Digital Avionics Systems Conference,* (pp. 1-12).

He, D., Chan, S., & Guizani, M. (2017). Drone-assisted public safety networks: The security aspect. *IEEE Communications Magazine,* 55(8), 218-224.

Huang, H., & Savkin, A. V. (2020). A method of optimized deployment of charging stations for drone delivery. *IEEE Transactions on Transportation Electrification,* 6(2), 510-518.

Karakurt, N. F., Hekimoglu, I., Guneri., (2021). Best worst metodu ile inşaat sektöründe risk değerlendirmesine yeni bir yaklaşim. *Mühendislik Bilimleri ve Tasarım Dergisi,* 9(4), 1141-1154.

Kamat, A., Shanker, S., Barve, A., Muduli, K., Mangla, S. K., & Luthra, S. (2022). Uncovering interrelationships between barriers to unmanned aerial vehicles in humanitarian logistics. *Operations Management Research*, 1-27.

Kellermann, R., Biehle, T., & Fischer, L. (2020). Drones for parcel and passenger transportation: A literature review. *Transportation Research Interdisciplinary Perspectives*, 4, 100088.

Khan, S. A., Kusi-Sarpong, S., Naim, I., Ahmadi, H. B., & Oyedijo, A. (2021). A best-worst-method-based performance evaluation framework for manufacturing industry. *Kybernetes, ahead-of-p*(ahead-of-print).

Kim, S. J., Lim, G. J., Cho, J., & Côté, M. J. (2017). Drone-aided healthcare services for patients with chronic diseases in rural areas. *Journal of Intelligent and Robotic Systems: Theory and Applications,* 88(1), 163-180.

Kusi-Sarpong, S., Gupta, H., & Sarkis, J. (2019). A supply chain sustainability innovation framework and evaluation methodology. *International Journal of Production Research,* 57(7), 1990-2008.

Kwon, H., Kim, J., & Park, Y. (2017). Applying LSA text mining technique in envisioning social impacts of emerging technologies: The case of drone technology. *Technovation,* 60-61, 15-28.

Lee, S., & Choi, Y. (2016). Reviews of unmanned aerial vehicle (drone) technology trends and its applications in the mining industry. *Geosystem Engineering,* 19*(*4), 197-204.

Lidynia, C., Philipsen, R., & Ziefle, M. (2017). Droning on about drones - Acceptance of and perceived barriers to drones in civil usage contexts. *Advances in Intelligent Systems and Computing,* 499, 317-329.

Liu, J., Guan, Z., & Xie, X. (2018). Truck and drone in tandem route scheduling under sparse demand distribution. In *2018 8th International Conference on Logistics, Informatics and Service Sciences (LISS),* (pp.1-6). IEEE.

Luppicini, R., & So, A. (2016). A technoethical review of commercial drone use in the context of governance, ethics, and privacy. *Technology in Society,* 46, 109-119.

Malveaux, C., Hall, S., & Price, R. R. (2014). Using drones in agriculture: Unmanned aerial systems for agricultural remote sensing applications. In *American Society of Agricultural and Biological Engineers Annual International Meeting 2014, ASABE 2014, 6*, (pp. 4075-4079). Montreal, Quebec Canada: American Society of Agricultural and Biological Engineers.

MarketsandMarkets. (2018). Drone logistics and transportation market by solution, sector, drone and region - Global forecast to 2027. Retrieved October 10, 2022 from https://www.marketsandmarkets.com/Market-Reports/drone-logistic-transportation-market-132496700.html?gclid=CjwKCAjw682TBhATEiwA9crl32DOAY0kbcNPMtIrhz3k6EK4ge2q61FsItR-WVQ0suTLtPHpIpIJ0xoCmT4QAvD_BwE

Marris, E. (2013). Fly, and bring me data. *Nature,* 498(7453), 156-158.

Merkert, R., & Bushell, J. (2020). Managing the drone revolution: A systematic literature review into the current use of airborne drones and future strategic directions for their effective control. *Journal of Air Transport Management,* 89, 101929.

Mohammadi, M., & Rezaei, J. (2020). Bayesian best-worst method: A probabilistic group decision making model R. *Omega,* 96, 102075.

Moshref-Javadi, M., Hemmati, A., & Winkenbach, M. (2021). A comparative analysis of synchronized truck-and-drone delivery models. *Computers & Industrial Engineering,* 162, 107648.

Moshref-Javadi, M., & Winkenbach, M. (2021). Applications and Research avenues for drone-based models in logistics: A classification and review. *Expert Systems with Applications,* 177, 114854.

Nakıboğlu, G. (2020). Drone taşımacılığı ve son-adım teslimatta kullanımı. *Çukurova Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi,* 24(2), 285-298.

Nyaaba, A. A., & Ayamga, M. (2021). Intricacies of medical drones in healthcare delivery: Implications for Africa. *Technology in Society,* 66, 101624.

Osakwe, C. N., Hudik, M., Říha, D., Stros, M., & Ramayah, T. (2022). Critical factors characterizing consumers' intentions to use drones for last-mile delivery: Does delivery risk matter? *Journal of Retailing and Consumer Services,* 65, 102865.

Otto, A., Agatz, N., Campbell, J., Golden, B., & Pesch, E. (2018). Optimization approaches for civil applications of unmanned aerial vehicles (UAVs) or aerial drones: A survey. *Networks,* 72(4), 411-458.

Özgüven, M. M., Altaş, Z., Güven, D., & Çam, A. (2022). Use of drones in agriculture and its future. *Ordu Üniversitesi Bilim ve Teknoloji Dergisi,* 12(1), 64-83.

Raj, A., & Sah, B. (2019). Analyzing critical success factors for implementation of drones in the logistics sector using grey-DEMATEL based approach. *Computers & Industrial Engineering,* 138, 106118.

Rathlev, F., Meyer, B., & Juerss, S. (2012). Innovative technologies for aerial survey of gas pipes. *Gas for Energy,* 5, 1-5.

Rejeb, A., Rejeb, K., Simske, S. J., & Treiblmaier, H. (2021). Drones for supply chain management and logistics: a review and research agenda. *International Journal of Logistics Research and Applications*, 1-24.

Rezaei, J. (2015). Best-worst multi-criteria decision-making method. *Omega,* 53, 49-57.

Rezaei, J. (2016). Best-worst multi-criteria decision-making method: Some properties and a linear model. *Omega,* 64, 126-130.

Sah, B., Gupta, R., & Bani-Hani, D. (2021). Analysis of barriers to implement drone logistics. *International Journal of Logistics Research and Applications,* 24(6), 531-550.

Sandbrook, C. (2015). The social implications of using drones for biodiversity conservation. *Ambio,* 44(4), 636–647.

Sandvik, K. B., & Lohne, K. (2014). The rise of the humanitarian drone: Giving content to an emerging concept. *Millennium: Journal of International Studies,* 43(1), 145-164.

Sanjab, A., Saad, W., & Basar, T. (2017). Prospect theory for enhanced cyber-physical security of drone delivery systems: A network interdiction game. In *IEEE International Conference on Communications (ICC)*. (pp. 1-6).

Scott, J., & Scott, C. (2017). Drone delivery models for healthcare. In *Proceedings of the Annual Hawaii International Conference on System Sciences*, (pp. 3297–3304). IEEE Computer Society.

Silvagni, M., Tonoli, A., Zenerino, E., & Chiaberge, M. (2017). Multipurpose UAV for search and rescue operations in mountain avalanche events. *Geomatics, Natural Hazards and Risk,* 8(1), 18-33.

Springer, P. J. (2013). *Military robots and drones: A reference handbook*. ABC-CLIO.

Stehr, N. J. (2015). Drones: The newest technology for precision agriculture. *Natural Sciences Education,* 44(1), 89-91.

Turğut, M., & Şeker, B. (2022). İnsansız hava araçlarının (İHA) taşımacılıkta kullanımına yönelik keşfedici bir araştırma: drone taşımacılığı ve uygulamaları. *Akıllı Ulaşım Sistemleri ve Uygulamaları Dergisi,* 5(2), 169-187.

Vattapparamban, E., Güvenç, I., Yurekli, A. I., Akkaya, K., & Uluağaç, S. (2016). Drones for smart cities: Issues in cybersecurity, privacy, and public safety. In *2016 International Wireless Communications and Mobile Computing Conference, IWCMC 2016* (pp.216-221). IEEE.

Wankhede, V. A., & Vinodh, S. (2021). Analysis of Industry 4.0 challenges using best worst method: A case study. *Computers and Industrial Engineering,* 159, 107487.

Yoo, W., Yu, E., & Jung, J. (2018). Drone delivery: Factors affecting the public's attitude and intention to adopt. *Telematics and Informatics,* 35(6), 1687-1700.