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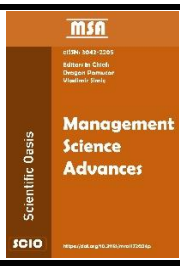

Exploring the Potential Applications of Artificial Intelligence in Parcel Delivery Systems

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ABSTRACT

This paper examines the potential applications and impacts of artificial intelligence within postal systems. A concise review of the relevant literature is presented, along with an overview of the most widely adopted artificial intelligence solutions implemented by leading global parcel delivery companies. To derive meaningful insights that may inform the implementation and operational use of artificial intelligence in this domain, a study is conducted involving expert opinions on the subject. There is a need to address issues of interoperability between different technologies and systems, as well as to provide adequate training for employees to operate within artificial intelligence-driven environments. Besides, the analysis highlights key priorities, anticipated benefits, and major challenges associated with the integration of artificial intelligence technologies into modern postal services.

1. Introduction

Artificial intelligence (AI) is becoming increasingly prevalent in modern business systems, including postal companies and parcel delivery networks. The application of AI has the potential to enhance the efficiency of business processes as well as the overall customer experience. Traditional postal systems are facing numerous challenges in the digital era, such as the rapid growth of e-commerce, the demand for faster delivery times, and the need to implement and develop sustainability strategies. In this context, AI offers innovative solutions to address these challenges, enabling companies to tailor their services to the needs of modern consumers [1].

The application of various AI solutions has become increasingly widespread in recent years, with the results demonstrating the remarkable potential of this concept. When considering its implementation in postal systems, two main perspectives can be distinguished: organizational and customer-oriented. Through the use of AI, postal systems can enhance the efficiency of mail proce-

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ssing facilities, resource management, and delivery route planning; they can also improve demand forecasting and enable personalized customer communication. For instance, machine learning algorithms can analyze data related to routes and weather conditions to support systems in recommending optimal delivery paths, while virtual assistants can provide 24/7 customer support by automatically responding to predefined queries generated based on previous user interactions. The implementation of AI has the potential to reduce operational costs and improve customer satisfaction. Accordingly, the introduction of AI-based models and solutions represents a significant step toward continuous improvement of business processes and progress toward greater sustainability [2].

Certainly, the implementation of AI in postal systems also presents some challenges. Issues such as high implementation costs, data privacy concerns, transparency, and the digital divide between developed and less developed countries (including disparities in technological advancement and the ability of employees to adapt) highlight the need for a responsible approach to AI adoption. Establishing a unified strategy for the integration of AI within the postal sector is becoming a priority to achieve a balance between technological advancement and the human aspect of service delivery.

This study explores the potential applications of AI in postal systems by analyzing the available literature and reviewing solutions implemented by leading global parcel delivery companies. The aim is to examine how AI can transform traditional postal operations, enhance the customer experience, and ensure the long-term sustainability of postal services in an increasingly competitive environment. The paper also presents the results of a study that investigated expert opinions on the implementation of AI in postal systems. The objective of this research was to identify key indicators that could guide the adoption and utilization of AI technologies in this sector.

2. Literature Review and Practical Implementations in the Postal Sector

The application of AI in postal and other delivery systems is on the rise, accompanied by a growing number of research studies in this field. An analysis of the available literature reveals several key areas in which AI demonstrates significant potential.

Route optimization is one of the most extensively studied aspects of AI applications in postal transport and last-mile delivery. Solutions based on machine learning, genetic algorithms, neural networks, fuzzy logic, and similar approaches contribute to reducing delivery times, particularly in urban areas where traffic conditions are complex. One of the main advantages of such solutions is their ability to analyze large volumes of data in real-time, including traffic conditions, weather patterns, daily and seasonal fluctuations, and other influencing factors [3-4].

AI-based analytical tools, such as regression models and big data processing methods, enable postal operators to forecast parcel volumes during specific periods. This capability supports more effective resource planning, including the allocation of vehicles, workforce management, and warehouse capacity optimization [5].

There is increasing pressure on postal and delivery systems to reduce their environmental footprint. In response, companies are developing various strategies, primarily aligned with sustainable development models. AI serves as a valuable tool for planning eco-friendly delivery routes, which in practice lead to reduced CO_2 emissions and optimized fuel consumption. Several studies indicate that combining AI with electric vehicles and other sustainable alternatives can significantly reduce harmful emissions [6-7]. Continuous improvement of service quality is one of the key prerequisites for maintaining competitiveness in the market [8-9]. AI-based tools can provide

highly efficient customer support, available 24/7. Additionally, these tools can be employed for marketing purposes, particularly in direct marketing, by identifying user habits and needs.

Furthermore, the analysis of customer preferences can be used to predict delivery times and adjust delivery schedules according to individual user expectations, thereby contributing to overall customer satisfaction [7,10]. The application of AI can also be of great importance in selecting the most appropriate delivery model, by simulating expert reasoning or assessing real-world conditions and relevant influencing factors. These factors are typically technical, social, economic, and environmental, and serve as the foundation for evaluating the sustainability of different alternatives [2,11].

Although AI offers numerous advantages, several challenges remain, including high implementation costs, the need for employee training, and concerns related to data security and privacy. Additionally, the integration of new technologies with existing systems can be complex and may require significant additional resources. These aspects are also well-documented in the literature [12-13].

When it comes to the real-world application of AI, sources from leading global delivery companies have been examined. The following section presents some of their AI-based solutions:

i. In the field of process optimization and automation, DHL employs advanced algorithms for route optimization, including dynamic route optimization that adjusts in real-time based on traffic conditions and shipment priorities. The company has also implemented warehouse robots that assist in the transportation and packing of parcels, thereby reducing workload and packaging time. For shipment dispatching, DHL has introduced the vision-picking concept, where employees wear smart glasses that use augmented reality (AR) to identify items for packaging. In terms of predictive analytics and enhancing the customer experience, DHL leverages big data and AI technologies to monitor and forecast customer demands [14]. This enables improved delivery time management and reduces the likelihood of errors. In the customer support sector, the company utilizes virtual assistants and natural language processing to automate the handling of customer inquiries and provide rapid responses [15]. During the delivery phase, DHL has been actively developing innovative technologies such as drones and autonomous vehicles, both of which rely on AI for operation. In the area of security, AI-powered cameras are used to detect suspicious activities within warehouses and sorting facilities, alongside established systems for parcel tracking.
ii. FedEx also employs AI models for dynamic, real-time parcel routing, taking into account factors such as weather conditions and traffic status [16]. These models enhance the accuracy of estimated delivery times, thereby enabling more efficient route planning. In collaboration with companies such as Nimble and Dexterity, FedEx has introduced AI-driven robots to automate processes like parcel sorting and truck loading [17]. Specifically, the DexR robot utilizes AI to efficiently stack packages of varying sizes within delivery vehicles. From a security perspective, the company has implemented the FedEx Surround system, which combines AI and sensor technology to enable real-time shipment monitoring. This system allows for the prediction of potential issues and supports proactive responses. Additionally, to integrate data from various sources and generate analytics and AI-based solutions, FedEx developed the FedEx Dataworks platform [18].
iii. To optimize delivery routes, UPS utilizes a system called on-road integrated optimization and navigation, which applies advanced algorithms to plan and optimize the routes taken

by drivers. This system analyzes data related to traffic, weather conditions, and other relevant factors to minimize mileage and fuel consumption, resulting in annual savings of approximately $200 million. Like other major companies in the sector operating at a similar technological level, UPS employs AI and automation to improve overall efficiency [19]. This includes the use of robots and machine learning to optimize warehouse space and accelerate the delivery process. From a security standpoint, UPS has implemented the DeliveryDefense system, which uses AI to identify potential risks of package theft [20-21]. The system analyzes data such as location, loss frequency, and other relevant factors to predict the likelihood of successful delivery and reroute high-risk parcels to more secure locations. To enhance the working environment, the company has also introduced the languages across logistics platform, designed to overcome language barriers among employees. This technology enables real-time translation, facilitating communication and training for staff from diverse linguistic backgrounds.

iv. As a company primarily focused on e-commerce and the delivery of purchased goods, Amazon leverages AI for predictive analytics to estimate future product demand and optimize warehouse inventory. Through demand forecasting, the company can proactively ship products to nearby fulfillment centers, thereby increasing the overall efficiency of the supply chain. Additionally, Amazon has introduced AI shopping guides to help customers more easily find products that match their preferences. These guides use AI to consolidate key product information, streamlining the decision-making process during online shopping. In its warehouses, Amazon employs solutions such as Kiva robots for the transport and organization of packages. These robots autonomously move products to packing stations, optimizing storage space and improving operational efficiency. The company is also known for its Prime Air concept, which involves the use of drones for parcel delivery.

Amazon has taken a step further by establishing the Amazon Web Services (AWS) cloud computing platform, which is offered to third parties. AWS provides over 200 fully functional services, enabling users to access a wide range of IT resources via the Internet. The platform offers an extensive suite of AI services that allow users to integrate intelligent functionalities into their applications without requiring in-depth knowledge of machine learning. The most well-known AI services offered by AWS include:

i. *Amazon Q* – An AI assistant designed for business use, allowing users to ask questions, generate content, and gain insights by connecting to a company's internal data. It can be customized to meet specific organizational needs and integrates with various data management systems.
ii. *Amazon SageMaker* – Enables developers and other stakeholders to quickly build, train, and deploy machine learning models in the cloud. It provides tools for working with a variety of algorithms and allows seamless integration with other AWS services.
iii. *Amazon Rekognition* – Provides pre-trained and customizable computer vision capabilities for extracting information and insights from images and videos. It is used for object, face, and text recognition, as well as for content modeling and media analysis.
iv. *Amazon Polly* – Converts text into speech, supporting multiple languages and voices. It is used to create speech-enabled applications, such as screen readers and interactive voice assistants.

v. *Amazon Lex* – Enables the creation of conversational interfaces using voice and text. It is well-suited for developing virtual assistants and other interactive applications that leverage natural language understanding.
vi. *Amazon Transcribe* – Automatically converts speech into text quickly and accurately. It is used for call transcription, generating subtitles, and speech analysis.
vii. *Amazon Translate* – A neural machine translation service that delivers fast, high-quality, affordable, and customizable translations between multiple languages. It helps overcome language barriers in applications and content.

The broad range of AI services [22] provided by AWS reflects the company's strategic focus on enabling intelligent, data-driven solutions across diverse industries. By offering scalable, cloud-based tools that simplify the integration of AI, AWS empowers organizations to enhance automation, optimize processes, and improve customer engagement. In the context of this study, AWS exemplifies how cloud-based AI platforms can play a pivotal role in supporting innovation, digital transformation, and long-term sustainability within modern postal and logistics systems.

The analysis of practical examples from leading global delivery companies highlights the significant role that AI already plays in transforming postal and logistics operations. Companies such as DHL, FedEx, UPS, and Amazon have successfully implemented AI-driven solutions across various segments of their operations – from route optimization and warehouse automation to predictive analytics, customer support, and security systems. These examples illustrate how AI contributes to greater operational efficiency, cost reduction, improved user experience, and enhanced adaptability to market demands. The practical applications presented in this section confirm that AI is not merely a theoretical concept, but a powerful tool with tangible benefits that is already reshaping the way modern delivery networks function.

3. Findings of the Expert Survey on the Application of Artificial Intelligence in Postal Systems

The following section presents the results of a survey conducted to assess expert opinions on the application of AI in postal systems. The study involved 10 experts in the field of postal transport, representing academic institutions, public postal operators, and private sector companies. The questionnaire consisted of a total of 10 questions, divided into a demographic section and a section focusing on the application of AI in postal systems. It was created using the Google Forms platform, through which responses were also collected.

In the first group of questions, the experts were asked to provide information on their gender and years of professional experience. The second group focused on their level of familiarity with the concept of AI, as well as the perceived benefits of AI in postal operations. Participants were then asked to prioritize the implementation of AI solutions for specific postal system tasks and to identify key challenges in adopting this concept. The survey also explored whether experts believe AI contributes more to the optimization of internal operations or to improving customer-facing services. Furthermore, respondents shared their views on the balance between human interaction and AI, as well as the potential impact of AI on employment. Finally, the last question asked participants to provide their predictions regarding the development of postal systems over the next five to 10 years.

Figure 1 presents the results of responses to the question "How familiar are you with the concept of AI?". Based on the results presented, it is evident that the majority of experts are well-acquainted with the concept of AI, while none reported unfamiliarity. This is primarily due to the widespread presence and growing integration of AI in modern business environments and everyday life.

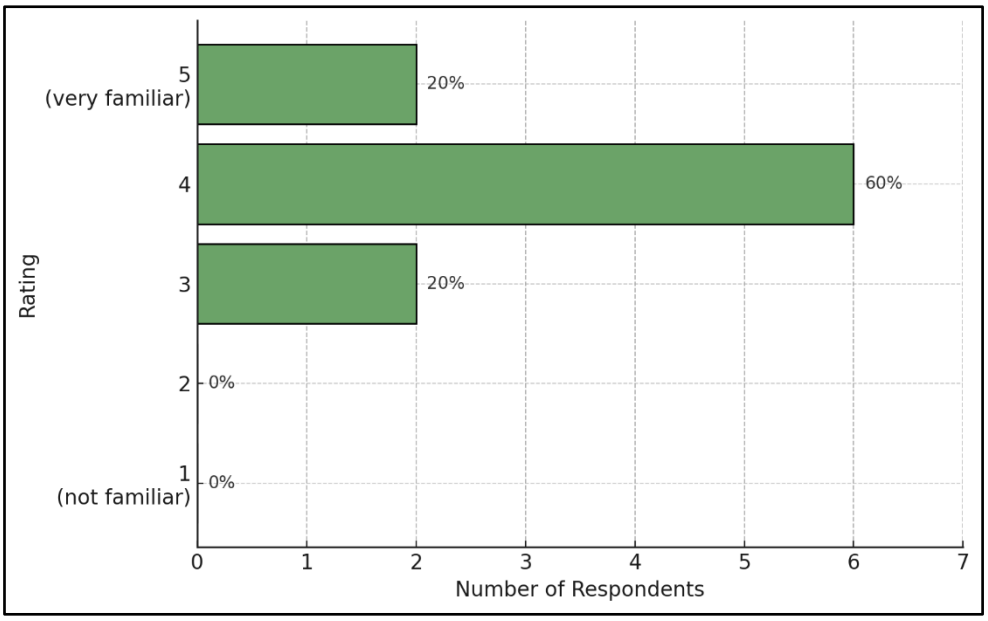

Fig. 1. Level of familiarity with the AI concept

Figure 2 presents the results of responses to the question: "In your opinion, what is the main advantage of applying AI in postal systems?". Expert opinions indicate that the greatest advantages of applying AI in postal systems can be observed in the areas of business efficiency improvement and customer experience enhancement. A review of the literature and available practical solutions confirms that these areas have received considerable attention, which further supports the experts' perspectives.

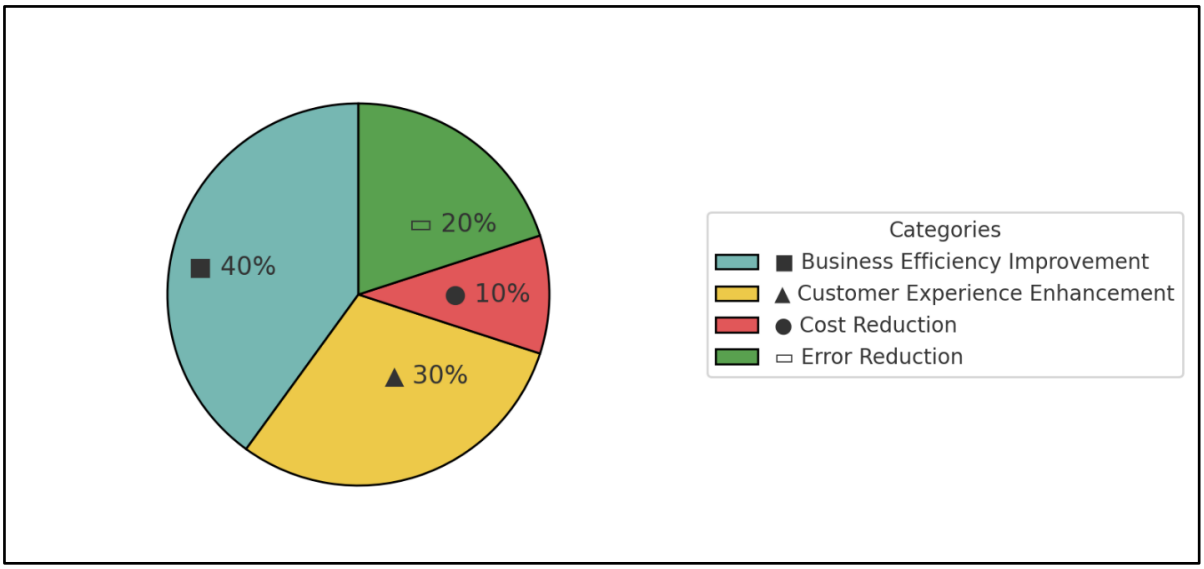

Fig. 2. Main advantage of applying artificial intelligence in postal systems

Figure 3 presents the results of responses to the question: "Please define the priorities for AI implementation among the selected tasks in the postal system", where the rating scale ranges from 1 (lowest priority) to 5 (highest priority). The obtained results indicate that three tasks stand out as priority areas for AI implementation: parcel processing, routing, and customer support. These are indeed tasks where AI technologies have already been successfully applied in systems where such solutions have been implemented, which further validates the experts' perspectives. Nevertheless,

the remaining two tasks also received respectable priority ratings, positioning them as relevant areas for continued monitoring and future development.

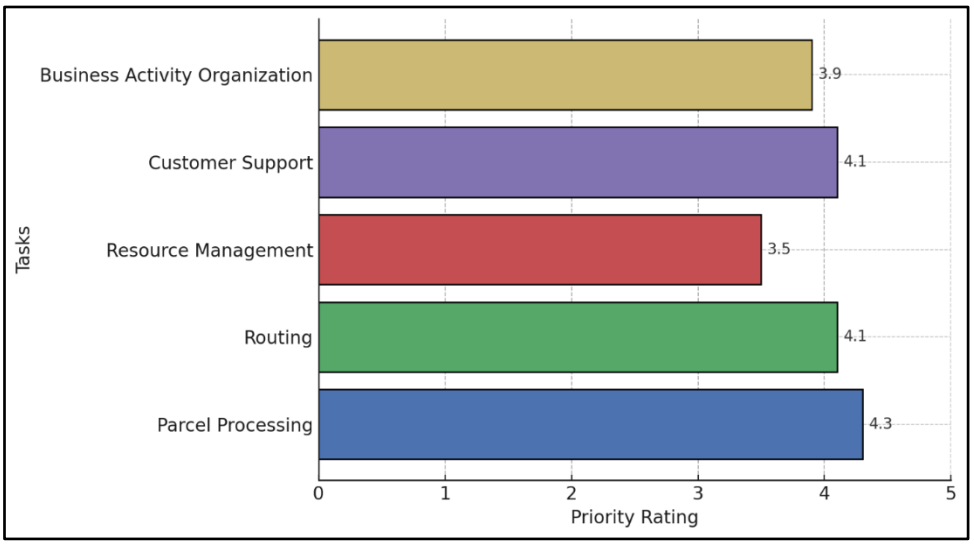

Fig. 3. Priority ratings for artificial intelligence implementation across selected tasks

Figure 4 presents the results of responses to the question: "Do you believe AI is more useful for operational processes or for improving the customer experience?". The majority of respondents believe that AI is more useful for improving operational processes. This may include tasks such as parcel processing automation, route optimization, resource management, and similar activities. This result reflects the perception that AI holds the greatest potential in enhancing internal organizational efficiency. A significant portion of respondents also recognize the value of AI in enhancing the customer experience, such as faster and more accurate responses to customer inquiries or service personalization. These aspects can be critical for customer retention and improving overall satisfaction. A third group of experts believes that AI can contribute equally to both operational processes and customer experience. This result suggests that many experts see potential in balancing the benefits of AI for both the organization and its users.

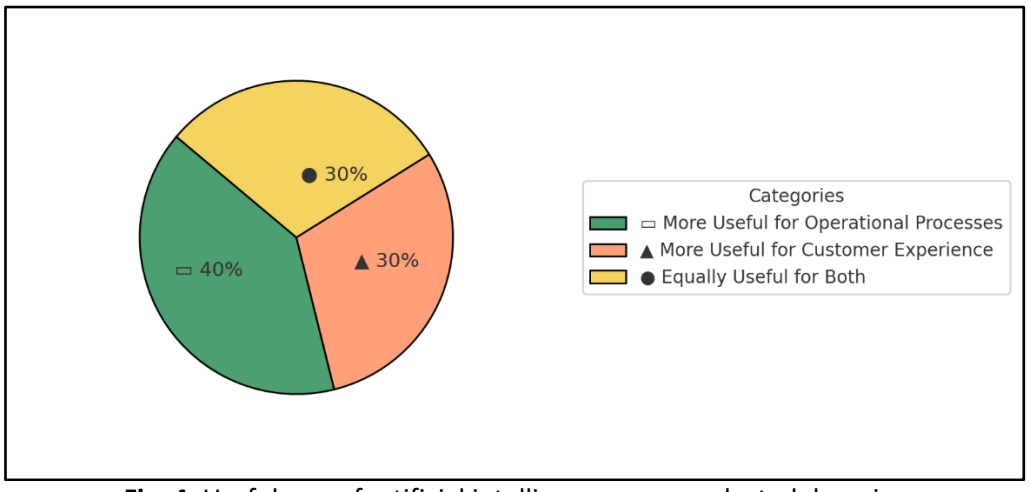

Fig. 4. Usefulness of artificial intelligence across selected domains

Figure 5 presents the results of responses to the question: "In your opinion, what are the biggest challenges in applying AI in postal systems?". When answering this question, experts were allowed

to select multiple options, which is reflected in the results, as can be observed in the chart. The most prominent challenges identified include data security, implementation costs, and the lack of technical infrastructure.

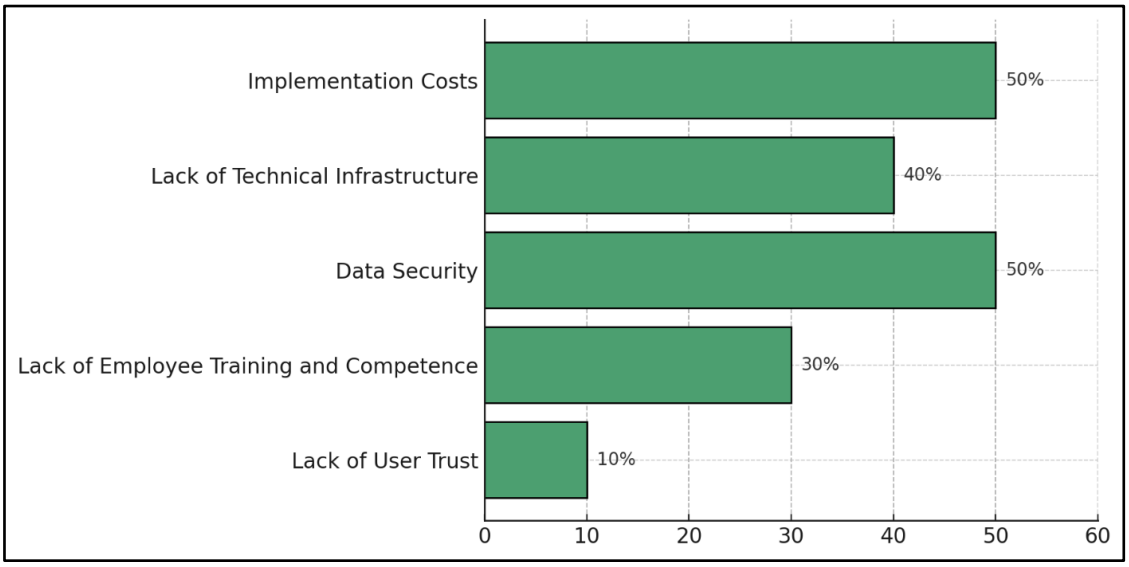

Fig. 5. Challenges in the application of artificial intelligence in postal systems

Figure 6 presents the results of responses to the question: "How important is it to maintain a balance between human interaction and automated AI processes in postal systems?". The results indicate a clear tendency toward maintaining a balance between AI and human interaction. This suggests that most experts believe that, despite the benefits of automation, the human element remains essential within postal systems. Regarding the impact of AI on employment in the postal sector, 20% of respondents believe that the number of jobs will significantly decrease, 50% expect a moderate decline, and 30% believe that there will be no reduction in employment. Additionally, a majority of experts (90%) believe that in the coming period, the application of AI in postal systems will enter a phase of moderate growth and gradual adaptation.

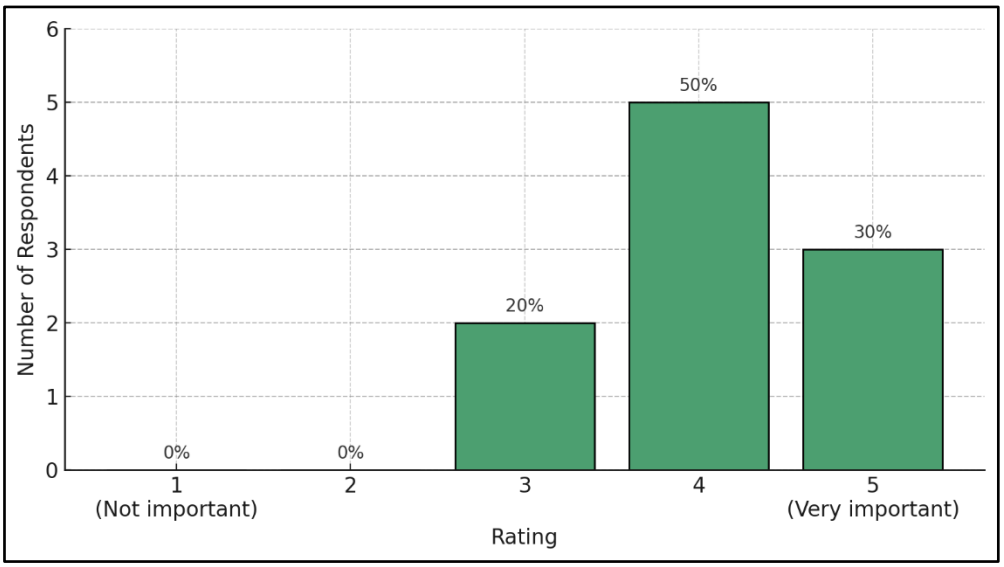

Fig. 6. Assessment of the importance of the balance between human interaction and artificial intelligence

4. Conclusion

The introduction of AI into parcel delivery systems represents a crucial step in transforming the logistics sector toward faster, more efficient, and more sustainable services. Through this concept, it becomes possible to plan resources more effectively, predict demand, process requests efficiently, and distribute shipments based on real-time conditions. AI solutions also enhance the customer experience, adding additional value to the overall service. However, in addition to these benefits, the implementation of AI also brings challenges such as technical complexity, high initial costs, and ethical concerns related to data privacy and security.

There is also a need to address issues of interoperability between different technologies and systems, as well as to provide adequate training for employees to operate within AI-driven environments. Future research may contribute to the development of more sustainable solutions, which will further shape global logistics and meet the increasing demands of the modern market.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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