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Reducing Last-Mile Delivery Time in Postal Services through the Use of Logistics Platforms

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Abstract

The study conducted an analysis and systematization of approaches to reducing delivery time in the final stage of logistics through the implementation and integration of modern digital platforms. The aim of the work is to conduct an analysis and systematization of methods for reducing temporal and resource indicators of last-mile delivery through the deployment of integrated logistics platforms, as well as to develop a conceptual model of such a solution. The methodology is based on a systems analysis of specialized publications devoted to the application of artificial intelligence, crowdsourcing schemes and alternative delivery methods. As a result, a platform architecture has been formed that integrates modules for adaptive routing, crowdsourcing resource management, organization of a parcel locker network and real-time analytics. It has been shown that the synergistic combination of these technologies ensures a significant reduction in average delivery times, a decrease in operational costs and an increase in end-user satisfaction. The scientific novelty lies in the development of a comprehensive model adapted to the characteristics and constraints of traditional postal operators. The work will be of interest to researchers in the field of logistics, managers of postal and courier services, as well as developers of software solutions for supply chain management.

Keywords: *Last Mile, Postal Services, Logistics Platform, Delivery Optimization, Dynamic Routing, Crowdsourcing, E-Commerce, Supply Chain Management, Artificial Intelligence in Logistics, Parcel Lockers.*

INTRODUCTION

Continuous expansion of the scale of global e-commerce against the backdrop of evolving consumer behavior imposes ever more stringent demands on the timeliness and cost-efficiency of logistics processes. The last mile phase — the final delivery segment from the distribution center to the recipient — traditionally exhibits the highest costs and the lowest productivity within supply chains. According to analytical reports for 2024, expenditures on the last mile segment reach up to half of the total delivery budget [1]. For classical postal operators relying on outdated infrastructure and static routing schemes, this situation poses a critical challenge to their competitiveness vis-à-vis more adaptive private courier services, thereby necessitating a fundamental rethinking of their operational models [12].

The scientific and practical relevance of this study is dictated by the absence of a comprehensive approach to unifying disparate technological solutions — dynamic route planning, deployment of unmanned aerial vehicles and expansion of networks of automated postal terminals — into a single platform that respects postal services' obligations for universal service.

The objective of this work is to analyze and systematize methods for reducing temporal and resource indicators of last mile delivery through implementation of integrated logistics platforms, as well as to develop a conceptual model of such a solution.

The scientific novelty lies in the development of a comprehensive model adapted to the specific features and constraints of traditional postal operators.

The author's hypothesis posits that the synergistic application of artificial intelligence algorithms for routing, adaptive delivery models involving third-party contractors and automated pick-up points within a unified digital solution will reduce average last mile delivery time and decrease operational expenses compared to traditional models.

MATERIALS AND METHODS

Contemporary industry reports and conceptual reviews frame the last-mile problem in the context of growing real-

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time requirements and digital transformation. Thus, Pitney Bowes notes that consumer demand for instant information on delivery status is driving radical changes in market shares among major carriers [1]. Similarly, McKinsey emphasizes that the development of digital logistics platforms is becoming a key source of competitive advantage in the sector through the integration of real-time data, machine learning and API-oriented ecosystems [12]. An extensive review by Boysen N., Fedtke S., Schwerdfeger S. [8] systematizes last-mile concepts from an operations perspective: the authors distinguish classical routing schemes, crowdshipping, pick-up stations and others, assessing their advantages and disadvantages at the operational level. Talebkhah M. et al. [11] examine the role of Industry 4.0 technologies (IoT, blockchain, advanced analytics) in the development of smart cities and logistics networks, showing how digital twins and platform automation can increase speed and reliability of delivery in the final stage.

In the field of algorithmic and optimization models, attention is focused on hybrid approaches that account for unstable conditions and the diversity of vehicles. Dieter P., Caron M., Schryen G. [2] incorporate driver behavioral characteristics into last-mile routing models, combining machine-learning methods for travel-time prediction with classical optimization heuristics, which reduces total delivery time by 5–10 % compared with traditional VRP algorithms. Pina-Pardo J. C. et al. [3] formulate a dynamic vehicle-routing problem with drone refueling for same-day urgent delivery, which enhances flexibility and response speed to demand changes during the operational day. Yu V. F. et al. [9] investigate a VRP with simultaneous pickup and delivery via a network of parcel lockers, which reduces last-mile time through a higher density of pickup and return points.

The topics of crowdshipping and hybrid fleets are actively evolving: Ghaderi H. et al. [7] propose an integrated platform for green delivery in which crowd couriers are engaged during peak hours to reduce congestion and emissions, and the assignment logic considers their ECO ratings and delivery speed. The approach by Hamid M., Nasiri M. M., Rabbani M. [6] likewise shows how a platform can dynamically allocate orders among its own fleet, drones and crowd couriers, optimizing the trade-off between cost and completion time.

Sustainability and consideration of customer preferences are becoming key in assessing platform effectiveness. Hajghani M. et al. [4] formulate an objective function that includes CO_2 emissions. At the same time, Jagoda A. et al[10] reveal intergenerational differences in the perception of sustainable delivery methods: younger consumers are willing to pay extra for green delivery, whereas older ones prioritize speed and price of the service.

Empirical and agent-based modelling methods complement theoretical developments. Marusak A. A., Krejci C. C., Mittal A. [5] show how the use of real geospatial data enhances the credibility of agent-oriented courier-allocation models and allows the exploration of demand hot spots in the urban environment.

Thus, despite significant progress, the literature shows a number of contradictions. For instance, some authors highlight the advantage of drones for accelerating the last mile [3], whereas others point to high costs and regulatory barriers to their large-scale adoption [6]. The environmental component is defined inconsistently across models: some studies employ a financial metric of the carbon footprint [4], while others use custom green ratings of couriers [7]. Moreover, most studies focus on algorithmic optimization, whereas issues of infrastructural constraints (degree of warehouse digitization, narrow urban street layouts) and the regulatory environment remain weakly covered. Interdisciplinary aspects are also insufficiently explored: the impact of end-user behaviour on platform adaptability and the security of personal data transfer when integrating IoT devices. These gaps indicate the need for comprehensive studies that combine technical, economic and sociocultural factors in last-mile analysis.

RESULTS AND DISCUSSION

Based on a systems analysis and in order to overcome gaps identified in the scientific literature, a conceptual model of an integrated logistics platform is described, aimed at radically reducing the time metrics of the last mile in postal services. This model relies on the synergistic interaction of three basic components — an intelligence core built on artificial intelligence algorithms, an adaptive resource ecosystem with crowdsourcing elements and a multimodal transport-logistics infrastructure (Fig.1.). At the focus of the architecture is a digital platform performing the functions of an operating system for the management and coordination of all processes of the final delivery stage.

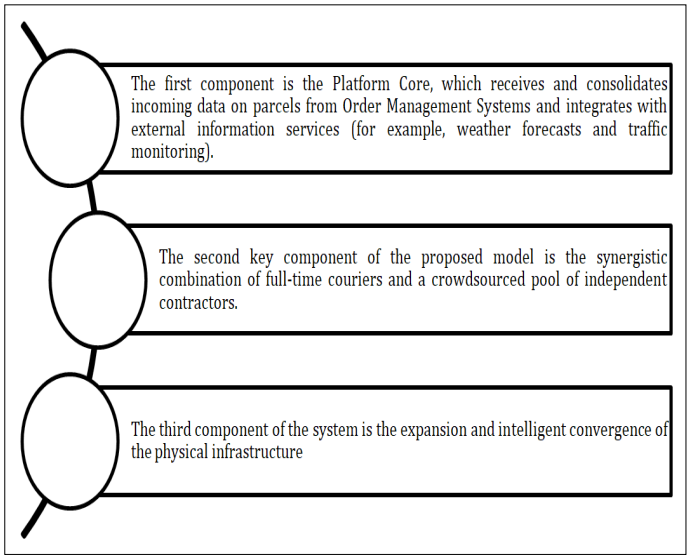

Fig. 1. Components of the integrated logistics platform model aimed at reducing the last mile time indicators in postal services (compiled by the author based on the analysis of [2, 4, 5, 8]).

The platform schematic depicted in Figure 2 comprises

several interconnected modules. At the center of the system is the core (Platform Core), which receives and consolidates incoming parcel data from Order Management Systems and integrates with external information services (for example, weather forecasts and traffic monitoring). Based on the aggregated data, four key components operate: the dynamic routing module, the resource management module, the customer interaction module and the analytics module.

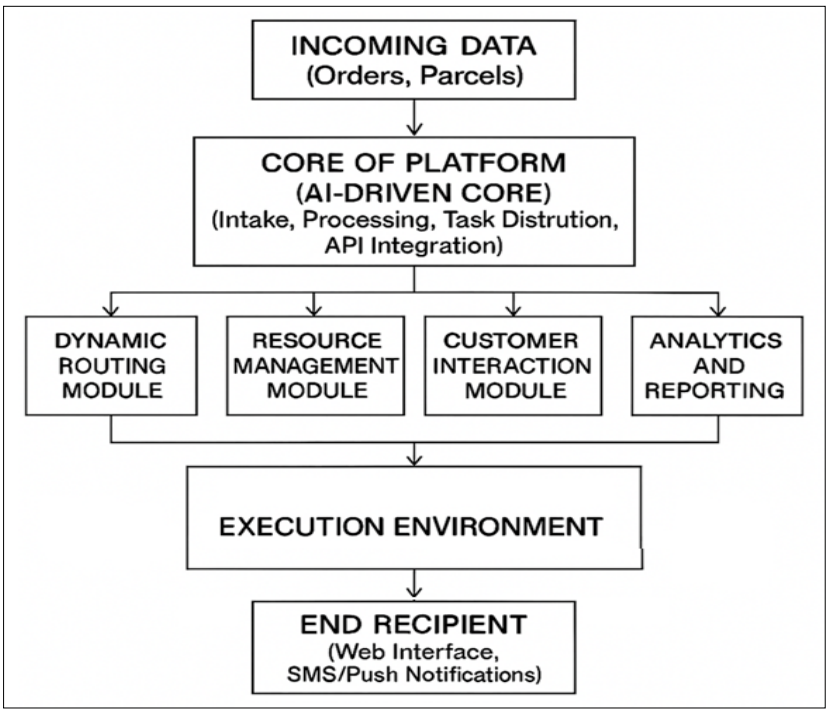

Fig. 1. Components of the integrated logistics platform model aimed at reducing the last mile time indicators in postal services (compiled by the author based on the analysis of [2, 4, 5, 8]).

Dynamic routing module serves as one of the fundamental technological components. Unlike the classical static paradigm applied in postal services, where planning of route chains is carried out several weeks in advance. The dynamic mechanism provides for continuous redefinition of optimal delivery trajectories in real time. Intelligent algorithms [2, 3] generate data on the actual traffic situation, arrival of unscheduled urgent orders, current courier workload, and clients' time preferences. This approach not only reduces total mileage and trip duration but also enables the setting of narrower and more precise delivery windows, significantly enhancing the quality of customer service. A comparative assessment of static and dynamic models is presented in Table 1.

Table 1. Comparison of static and dynamic routing models in postal services (compiled by the author based on the analysis of [2, 4, 9, 11]).

Parameter	Staticmodel (traditional)	Dynamic model (platform-based)
Routeplanning	Pre-planned, fixedroutes	Real-time, adaptive
Adaptabilitytochanges	Low (does not account for traffic, new orders)	High (automaticrouterecalculation)
Transport utilizationefficiency	Medium, possible high deadhead mileage	High, optimization of load and mileage
Customer service	Wide delivery windows (e.g. from 9 to 18)	Narrow delivery windows (1-2 hours), ability to modify
Operatingcosts	High due to inefficiencies and rework	Reduction by 15-25 % due to fuel and time savings
Technologies used	Manualplanning, basicnavigators	AI, machine learning, real-time GPS tracking

The second key component of the proposed model consists in the synergetic combination of in-house couriers and a crowdsourcing pool of independent contractors. By integrating permanent staff with selectively engaged, verified couriers, adaptive resource management is achieved under variable demand conditions. During low-load phases (for example, in the middle of the workday) the bulk of deliveries is assigned to in-house employees, ensuring process stability and uniform quality. Conversely, during peak loads (evening hours, pre-holiday periods) the platform automatically expands the pool via crowdsourced couriers selected according to geographic location, rating, and current availability [5, 6]. This scheme eliminates the need to maintain an excessive workforce while simultaneously guaranteeing compliance with standard delivery times during periods of heightened demand.

The third component of the system involves the expansion and intelligent convergence of the physical infrastructure. In this concept the platform regards the network of automated parcel terminals and pickup points not as passive stations but as active information-logistics nodes [8]. A specialized routing algorithm evaluates the spatiotemporal characteristics of deliveries, demonstrating that aggregating multiple shipments into a single terminal within a defined area and time window yields greater efficiency compared to sequential visits to numerous addresses. Meanwhile, the user receives a notification about the possibility of early parcel retrieval from the nearest terminal along with a unique access code. This approach not only accelerates the overall delivery cycle but also radically reduces the number of failed delivery attempts, one of the key factors driving last mile costs.

Analysis of the results has revealed that intervention by the proposed model produces a multiplicative synergetic effect unattainable when its components are used in isolation. Thus, deployment of AI-based routing without flexibly scalable resources proves ineffective: in the absence of engaged couriers, urgent route adjustments cannot be executed. Similarly, crowdsourcing outside the context of an intelligent platform devolves into a spontaneous, poorly managed process, and the autonomous operation of parcel terminals without integration into a unified routing system reduces their role to a secondary, passive option. Only a unified digital ecosystem, equipped with mechanisms for self-learning and adaptive reconfiguration, enables the desired level of flexibility and reliability. For postal service operators this translates into a shift from a static, capital-intensive model to a dynamic, resource-efficient system, and for recipients into a noticeable reduction in wait times, improved forecast accuracy, and a variety of convenient parcel retrieval options[7, 10].

Implementation of such a platform is accompanied by a number of challenges, among which are substantial initial investments in IT infrastructure, extensive workforce retraining, and overcoming the inertia of established business processes. However, the potential benefits in terms of strengthened competitiveness and enhanced customer loyalty clearly outweigh the costs, in alignment with current trends in the global logistics market.

CONCLUSION

The research conducted enabled the classification of contemporary methodologies for optimizing last mile logistics and the identification of dominant technological and operational trends. A comparative analysis of specialized publications demonstrated that despite the widespread application of individual tools: AI routing, crowdsourcing, networks of autonomous parcel lockers — there are no comprehensive methodological solutions that integrate these components into a unified system adapted to the operational realities of standard postal operators.

The key achievement of this work consisted in the development of a conceptual model of an integrated logistics platform based on the combination of an intelligent software core, a hybrid personnel-resource potential and multimodal infrastructure. This model functions as a strategic roadmap for the transformation of postal services: the implementation of the platform ensures the transition from static inflexible routing to a dynamic delivery scheme that operationally adapts to changing conditions. This, in turn, directly contributes to the realization of the research objective — the substantial reduction of delivery time and the optimization of operational costs.

The hypothesis put forward at the beginning of the research that the synergistic integration of advanced technologies within a single platform is capable of ensuring an increase in last mile efficiency received theoretical confirmation. Looking ahead, it is advisable to focus further studies on the development of specialized algorithms for the modular components of the platform, on conducting economic and mathematical modeling of its implementation using the example of a specific regional postal operator and on organizing pilot projects to verify the theoretical propositions in practice.

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