



SMART CITIES AND CITY LOGISTICS

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Abstract

Because of the constant influx of people, big cities are growing, and life in them is getting more challenging. City governments face increasing challenges related to the citizens supplying water and food, energy, public transport, roads, health services, and others for waste removal, recycling, and storage. Cities adapt to new conditions by using new technologies and innovative solutions. Cyber-physical systems, digitization, networking, cloud computing, the Internet of Things, and blockchains are tools that can help smart cities function. In this review paper, based on a review of relevant literature, the authors discussed some possible models for meeting the logistical needs of citizens in Smart cities. They focused on Smart-city technologies. The subject matter of this article is very complex and covers several disciplines, such as management, transport, and information technologies. Few have mastered the necessary knowledge in all these areas. The authors wish that this multi-dimensional presentation of the current situation will be helpful to those who deal with the organization of life in cities, logistics, or the application of information technologies in business organizations, but also ordinary citizens who are not yet familiar with these problems. The article should allow the reader to see the complexity of last-mile delivery and encourage it to use its potential to get involved in solving this problem.

Keywords: Smart City; supply chain; blockchain; logistics; last-mile delivery.

1 INTRODUCTION

The world we live in is changing rapidly. According to predictions, cities will include over 60% of the world's population by 2050 (Todorova, 2022). 70

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percent of the total energy will be consumed in cities. The total emission of greenhouse gases in cities will also reach 70%. (Safonov, Kirsanov, & Čekerevac, 2022, p. VIII) That will bring many problems to their management. Citizens have a daily need to use very diverse resources and services. With the growth of cities, the challenges in their functioning also grow. This increases the need for the implementation of the Smart City



concept. That is why the idea of building smart cities was promoted more and more frequently in the previous decade. The common understanding is that the very idea of creating smart cities that will be comfortable, economical, sustainable, and environmentally friendly dates back to the 1960s (Vallianatos, 2015), but also to the year 2008 when IBM launched the term "A Smarter Planet" (Gavin, 2022). However, the idea is much older and goes back thousands of years. No one certainly wanted to build cities that were not comfortable living in. Only the circumstances changed over time, so different criteria were dominant at various times. Once cities needed high and strong ramparts, now comfortable housing, transportation, and what is considered an upgrade in living standards. Also, now we have more advanced technologies at our disposal, so we can use them to achieve the stated goals. This primarily refers to the mass application of information technologies in what is offered to the population. The most important thing is that this application must be in harmony with the environment so that cities can survive.

Information technologies are an indispensable factor in managing transportation, supply, logistics in general, water supply, waste management, and other services. Smart cities with the help of new technologies must create a favorable atmosphere for the life and work of their citizens. (Cekerevac & Bogavac, Logistics and last-mile delivery in smart cities, 2023)

Regarding logistics problems, Cekerevac and Bogavac discussed them in (Cekerevac & Bogavac, Logistics and last-mile delivery in smart cities, 2023). Here we will focus on city logistics and last-mile delivery. The term "last-mile delivery" refers to the last step in the supply chain regardless of its duration. The fact that it accounts for more than 50% of the total transport costs speaks of the importance of last-mile delivery. (Cekerevac & Bogavac, Logistics and last-mile delivery in smart cities, 2023)

This review study aims to systematize and summarize information about the state and trends in the last link of the logistics chain, last-mile delivery. Given the current trends in the cities' reorganization, the article focuses on logistics in the so-called smart cities. Due to the current interest of authors in finding alternative solutions, they paid specific attention to the process organization using blockchain technology.

2 MATERIALS AND METHODS

The study's conceptual basis is the system-functional approach. In this research, the authors used generally used scientific methods and techniques (deduction, comparison, induction, statistical analysis, scientific abstraction, and generalization), and methodological development tools (statistical grouping, graphical interpretations, etc.) to support theoretical positions and argumentation of conclusions. The authors used high-quality data obtained from relevant literature sources. The mentioned methods, used in solving the tasks set, made it possible to ensure a high level of representativeness of the results and the conclusions in the context of a unique algorithm for achieving the goal. The proper and complete citation of all used sources enables a high reproducibility of research results.

The authors used publicly available literature listed in the chapter References and the results of their previous research published in scientific papers and at scientific conferences.

During the research, the research question (A) was raised: What is the relationship between logistics service quality and smart-city technologies?

The null hypothesis for the research question can be set up as:

$H_{0,A}$: There is no correlation between logistics service quality and smart-city technologies.

The alternative hypothesis for the research question can be set up as:

$H_{a,A1}$: There is a correlation between city logistics service quality and smart-city technologies.

$H_{a,A2}$: There is a correlation between city last-mile delivery quality and smart-city technologies.

3 RESULTS AND ANALYSIS

3.1 Smart cities

From 2.5 billion people in 1950, 751 million (30%) lived in cities. The urban population increased rapidly. From 7.66 billion in 2018, 4.2 billion (54.8%) lived in cities. (Cekerevac, Prigoda, & Bogavac, 2022) If the predictions come true, the share of the urban population will increase to 68% by 2050. Now there are more than 8 billion people

on the planet Earth. Despite Asia's low urbanization, 54% of the world's urban population lives there. Europe and Africa are the next with 13% each. Projections show that people gradually shift from rural to urban areas, even from smaller to larger cities. Given the overall growth of the world's population, an additional 2.5 billion people could inhabit urban areas by 2050. According to the UN report, the largest share, close to 90% of this growth would be realized in Asia and Africa (UN, 2018).

To satisfy diverse and growing needs, from food to what is considered a luxury, changes must be preceded by the development of technologies. If they fail to meet the needs of their residents, cities are at risk of decay. There are countless such cities, and Chicago, the third largest city in the USA, can serve as an example. Despite immigration, Chicago lost about one million inhabitants in the last 70 years, from 3.6 million (1950) to 2.7 million (2020). (US Census Bureau, 2020). Economic conditions influence the outflow of citizens undoubtedly. Also, if all city services do not function satisfactorily, living conditions may become unsustainable. Such situations can arise suddenly, e.g. strikes of urban cleaning workers, e.g. in Rome (Reuters, 2018) (Matthews, 2021), Amsterdam (Hue, 2007), (Kievith, 2023), etc. That means that improving technology is not enough in itself. The human factor is very important.

To be "smart", the city must invest in the development of existing technologies and look for better solutions at the same time. For these purposes, the city must have relevant data when making decisions. In addition to the above, it is necessary to prepare residents for life in smart cities and training in the application of new technologies.

Smart cities developed different technologies to make citizens' lives easier. They can be grouped, and the most expectable groups are:

- Smart IoT devices,
- Smart energy,
- Smart mobility and transportation,
- Smart waste management, and
- Smart buildings.

Given the complexity of the topic, we will not deal here with all the issues that may arise in smart

cities. We will focus on logistics organization models and technology. For the needs of transportation, it is necessary to have an elaborate plan for continuous improvement of the intelligent transportation system. It will inevitably have to include a mass application of IoT, traffic scanning, developed video surveillance, electronic toll collection, and a system for finding free parking spaces and places to supply vehicles with electricity. Some of the cities faced with a shortage of parking spaces have introduced special parking spaces that can only be used for loading or unloading during store hours. After the end of working hours, other citizens can also use them. The correct selection of those places can greatly facilitate the problems of supplying stores and delivering goods to customers in the area. Most of the activities are based on massive digitalization.

3.2 Smart Cities and city logistics

Due to the growth of cities and their specificities, city logistics has become a significant segment of logistics. The term city (or urban) logistics usually refers to the ways and means used in urban areas to distribute cargo. City logistics can belong to any segment of the logistic chain, but usually, it belongs to middle-mile or last-mile stages. Sometimes middle-mile delivery can have several stages in the same city. Figure 1 illustrates such a situation in the example of a letter traveling from Belgrade (Serbia) to Maykop (Russian Federation).

A good city logistics model strives to apply appropriate strategies to improve efficiency and reduce harmful emissions, traffic congestion, and other negative side effects. Since the process is realized within cities, it hugely depends on the city in which it takes place.

In addition to what is common for all logistics chains (organization of transportation, roadways, GPS with its components, sensors, etc.), for city logistics, for city logistics modeling are crucial the location of logistics centers, the quality of city traffic, passability of streets, data on current and planned works that may affect some streets closing or the limitation of the width of the passage, the possibility of parking, the variety of the vehicle fleet and other, including the provision of a sufficient number of drivers and support workers.



Fig. 1 An example of a city logistics problem. Person A sends a letter to Person B

The environment dictates many constraints that a carrier must deal with to meet the demands of urban customers and business partners. At the same time, carriers must find new innovative solutions, which are often ad hoc solutions. This was also the case at the beginning of the COVID-19 pandemic when customers suddenly changed their previous habits. Home delivery has become a significant and even dominant way of selling. Retailers had to adapt quickly, and transporters faced major challenges. Many small vehicles had to be provided to transport small quantities of goods. Bicycles have become a significant factor in transportation. Such a rapid change brought, in addition to a change in the way of transporting goods, a change in the way of paying for delivered goods and charging for services rendered.

Current city logistics models have introduced many novelties in supply chains. Many models in middle-mile delivery often contain several small and micro hubs where shipments arriving from logistics centers are repackaged and distributed according to recipients' locations. These hubs are most often located within cities, which allows for a significant reduction in delivery costs. One of the best examples of this model is the delivery of postal items.

Because of their specifics, some authors, such as Rodrigue and Dablanc (2021), began to insist on conceptual differences and separate city logistics and supply chain management. He drew parallels between supply chain management and city logistics and addressed differences as organization v regulation, private v public actors, network v space, and efficiency v effectiveness. However, it is debatable whether it is justified or

not. City logistics is part of the supply chain. It has specifics, but those specifics also depend on whether it is part of middle-mile or last-mile delivery. (Cekerevac & Bogavac, Logistics and last-mile delivery in smart cities, 2023)

The goal of modern city logistics is timely procurement with the idea that stocks in stores are minimized and that they are aimed at satisfying seasonal consumption. Modern customers want goods promptly, eventually, tomorrow. That means smaller loads and higher frequency in distribution. The need for couriers and express delivery increased. According to estimates (Rodrigue & Dablanc, 2021), the movement of goods in urban conditions accounts for 20 to 30% of the kilometers traveled by all vehicles in the urban area.

Several smart-city technologies are significant for city logistics:

1. Intelligent Transportation Systems (ITS) helps to optimize traffic flows and reduce congestion. That includes traffic lights adjusted to real-time traffic conditions and tools for managing traffic incidents and redirecting vehicles to avoid congestion.
2. Fleet management systems use advanced telematics and GPS technology to monitor the locations, status, and vehicle fleet performance. That can help optimize routes, improve delivery times, and reduce fuel consumption. IoT use can also help control fuel tanking (Cekerevac, Matic, Djuric, & Celebic, 2006).
3. Predictive analytics can help to identify areas where traffic congestion is likely to occur,

enabling logistics companies to reroute their vehicles and avoid delays.

4. Smart Parking: Smart parking solutions use real-time data to help drivers find an available parking spot quickly and easily. That can reduce the time spent circling the block looking for parking, thereby reducing congestion and improving traffic flow.

Therefore, we can say that there is a correlation between city logistic service quality and smart-city technologies. Smart-city technologies using can improve the efficiency, safety, and sustainability of city logistics systems. Smart traffic management systems, for example, can optimize delivery routes and reduce congestion, while smart parking systems can streamline the delivery and pickup of goods. Additionally, real-time tracking and monitoring of vehicles and cargo can improve transparency and reduce the risk of theft or loss. Overall, the integration of smart-city technologies can enhance the quality and reliability of city

logistic services, leading to greater customer satisfaction and economic benefits.

3.3 Last-mile delivery and smart cities

Last-mile delivery¹ is becoming one of the most significant issues in supply chains. The main goal is to deliver packages from the final distribution hub to the customer at an acceptable price and within the agreed time frame. Modern buyers have the option of tracking their shipments during the entire journey from the seller to the delivery point. The period from the arrival of the shipment to the city until delivery is crucial for the overall picture of the distributor. Convey's research found that 84% of customers are not in the mood to buy again from a retailer that has not performed well in last-mile delivery. According to the same research, 98.1% of customers consider last-mile delivery to be key to brand loyalty. (Convey, 2018). Fig. 2 shows what customers think about how the brand should react if a package misses its estimated delivery date

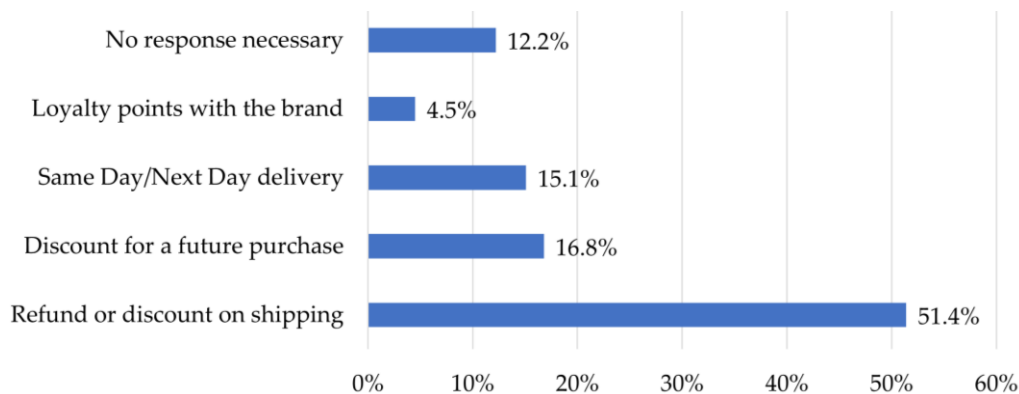


Fig. 2 How the brand should react if the package misses its estimated delivery date – from the customers' point of view

Source: Authors' visualization based on Convey (2018)

The same research showed that 62% of those surveyed stated that cost is the most significant factor in delivery, as shown in Fig. 3. According to Dolan's research (2023), last-mile delivery accounts for more than 53% of total delivery costs.²

The two biggest challenges for last-mile delivery are the number of packages that must be delivered and the number of recipients' addresses. Most often, recipients receive one parcel at their

addresses. The transporter is faced with solving the traveling salesman problem and the vehicle routing problem. Both problems belong to the NP-hard problems. Delivery is also affected by many additional factors. These may relate to priorities and scheduled delivery times, delivery vehicles drivers' schedules, vehicles' capacities, expected traffic congestion, the number of locations where shipments must be delivered, etc. At the same time, these factors do not always have the same

¹ Also known as last-mile logistics.

² The term last-mile delivery should not be taken literally but as delivery from the last in a series of distribution hubs.

weight. Depending on the situation, each of them can become dominant. The carrier must consider the expected stops for the delivery of the shipment at the delivery points, as well as the availability of nearby parking spaces. It must choose the proper delivery vehicle size to avoid situations where the vehicle cannot reach its destination. Repeated delivery is at the transporter's cost.

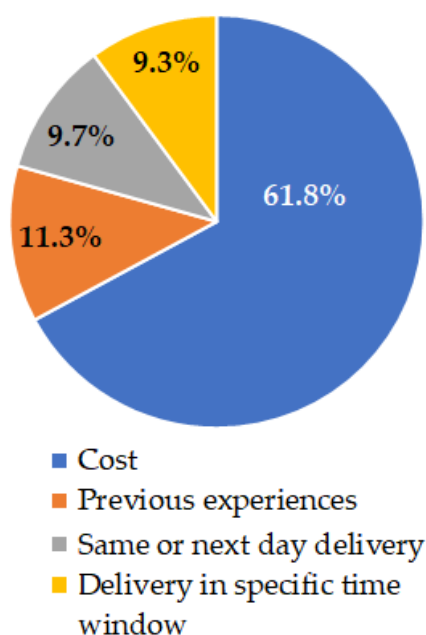


Fig. 3 The most important factor in delivery
Source: Authors based on Convey (2018)

Often packages cannot be delivered to the client. One of the reasons may be the absence of the recipient from the place of reception. Undelivered shipments require new communication with the recipient and a repetition of the delivery process.

With a small number of parcels and clients, an application of brute force can solve organizational problems. But, with many clients and parcels, it is necessary to use some predefined algorithms (branch-and-bound, branch-and-cut, or branch-and-price algorithms) and algorithms that use techniques reminiscent of linear programming. Because of the complexity of the problem, there are no ideal solutions. Carriers strive for an optimal solution by applying heuristics and meta-heuristics and often resort to hybrid methods that include all or some of the mentioned procedures (Kumar & Panneerselvam, 2012). Smart cities can

help in finding optimal solutions by providing up-to-date data on traffic conditions.

Many factors affect the price of last-mile delivery. Costs as an effect of the process of spending existing values to cover all the phenomena of the company represent the sum of the values spent in the realization of the set task. As presented in Cekerevac and Bogavac's article (Logistics and last-mile delivery in smart cities, 2023), in last-mile delivery, all costs are common for all companies in transporting goods as:

- the price and depreciation of the vehicle,
- fuel consumption,
- salaries of drivers and workers who work on the selection and loading of packages,
- route planning and records making,
- cost of software, and many other costs.

But there are also some specifics. Some costs are more pronounced. When parcels are transported on the highway when large vehicles run at a constant speed, fuel consumption is up to 50% lower than in urban conditions when vehicles run at low speeds with many stops, accelerations, and sudden braking³. With more stops, vehicles will be underutilized and idling longer. Also, compared to driving on the highway, the driver will spend incomparably more time behind the wheel for the same mileage, with significantly greater fatigue. Because in cities transporters use smaller vehicles, they need more drivers. When the complexity of the route increases, the same does the number of out-of-route miles. (Cekerevac & Bogavac, Logistics and last-mile delivery in smart cities, 2023) According to the research (Hochfelder, 2017), up to 10% of traveled kilometers refer to out-of-route miles.

In recent years, at least declaratively, increasing attention has been paid to sustainable development. New and stricter requirements to protect the environment are constantly being set. They force companies to introduce the care of the product during its entire life cycle. Manufacturers also must use as many recycled parts as possible. In the EU, according to Waste Act: Directive 2008/98/EC on waste (EU, 2008), what cannot be recycled must be disposed of safely so it will not

³ Depending on the truck model, road conditions, and driving style, fuel consumption ratios for driving on highways and cities can be different. Normally, trucks consume between 20 and 35 liters per 100 km on the

highway, depending on the load and speed. Fuel consumption in the city can be between 30 and 50 liters per 100 km because of frequent stops and movements in crowds.

endanger the environment later. The end-user, in the case of last-mile delivery, is a citizen. That is why we can expect that the lifespan of the product will expire right there. The location of goods delivery becomes the starting point in the new first-mile delivery, and that part of city logistics is connected to the waste management business group. Because of the human orientation and taking care of the product even after its useful life, we can hear the term "Reverse Logistics 5.0" more and more frequently, for example at Frederico (2021, p. 49), Jafari, Azarian, and Yu (2022), and others. While Industry 4.0 focused on autonomous solutions aiming to replace human workers, Industry 5.0 strives for harmony between people and technology. Likewise, Logistics 4.0, which relied on autonomous smart logistics systems, now tends to transform itself following the idea of sustainability. (Sun, Yu, & Solvang, 2022)

Companies have a specific problem with returned shipments. When shopping online, there is a high percentage of returned items. Their share reaches 20% (Dopson, 2021). In cases of returned shipments, the seller must either deliver replacement goods at his expense or return the money. To avoid the costs of the administrative tasks and taking the goods over, the seller often delivers new goods without taking already delivered shipment. The seller must calculate the costs of delivering the goods considering the possible return of the goods.

Large companies, national or multinational, very often offer the same prices for their products throughout the territory of a country, including the prices of delivery to the customer's address. This means that some average shipping prices are considered. This can be justified because neither the entire production is concentrated in one place, nor all the customers are concentrated in one place. Thus, some products travel longer from the place of production to the local logistics hub, but they travel shorter from the local logistics hub to the place of delivery and vice versa. It is possible to calculate the cost of transportation for each product individually, but at the time of purchase, it is usually not feasible, because of the unknown quantity and number of packages that will be transported from the manufacturer to the logistics

center, from the logistics center to the local micro-hub, and the local micro-hub to the place of delivery. Given that the last-mile delivery cost is more than half of the total transportation cost, it is necessary to choose the location of micro-hubs carefully. (Novotná, Švadlenka, Jovčić, & Simić, 2022) The correct choice of location can be decisive for the survival of the transporter. That is why, in addition to the investor's intuition, the transporters use much more sophisticated techniques such as e.g., multi-criteria decision-making techniques.

One way to simplify and cheapen last-mile delivery is to implement an automated network of parcel delivery lockers (APLs). The idea is to set up lockers at convenient locations in the city where the carriers will leave shipments, and recipients will be able to open the lockers and pick up the shipments by applying the appropriate codes. That improves distribution in the last mile by reducing the number of vehicles, the distance that vehicles travel, and the number of vehicle stops. This can also reduce the impact of transportation in the last mile on the environment. Delivery of parcels to the store closest to the customer's address is already in use. The customers pick up the goods at the chosen store at a time that suits them. The analysis carried out in the paper (Sawik, Serrano-Hernandez, Muro, & Faulin, 2022) gave encouraging results⁴.

Among others, Yu et al (Yu, Susanto, Yeh, Lin, & Huang, 2022) dealt with this problem, but they also included the possibility of parcels' simultaneous delivery and retrieval. Their research covered three possible places of goods delivery and pickup:

- home,
- parcel locker, and
- home or parcel locker.

Previous approaches have considered the simultaneous delivery and pickup problem with time windows (SDPPTW) in the cases of delivering shipments to customers and picking up return shipments only from customers. (Yu, Susanto, Yeh, Lin, & Huang, 2022) The authors named the new approach the vehicle routing problem with simultaneous pickup and delivery and parcel lockers (VRPSPDPL). Their research

⁴ The authors used Anylogic software and a CPLEX solver.

aimed to reduce the total costs of transportation to the lowest possible extent. Since there are no reference instances, they generated new ones based on the SDPPTW benchmark instances. As a limitation, they introduced into the model that home delivery and pickup can only be done in specific time windows, but there is no such limitation for parcel lockers. Experimental results confirmed the proposed algorithms' efficiency and effectiveness in solving VRPSPDPL. The authors claimed that their algorithms are more efficient than Gurobi⁵, even in small- and medium-size instances. In the case of large-size instances, new models are significantly better than Gurobi (Yu, Susanto, Yeh, Lin, & Huang, 2022). The proposed model is not omnipotent and should be improved by introducing realistic parameters such as the diversity of the carriers' fleets by types, sizes, and used energy sources, as well as by determining the optimal number and arrangement of parcel lockers.

Although parcel lockers seem the promising solution for last-mile delivery, it should be borne in mind that the final stage of goods delivery is left to the buyer. One should also keep in mind the limitations of this delivery method, as it is unlikely that the customers will agree to carry the refrigerator, furniture, or ceramic tiles from the location of the locker to their address.

One of the possible additions to such a system is crowd shipping. It is also suitable for sellers with small physical stores as it allows them to leverage their stores' network to compete with the high standards of big companies. They can deliver their goods on the same day and fulfill the increased demand and application of e-commerce. The idea is to involve amateurs in last-mile delivery instead of professional transporters. The transporters are people whose journeys in certain situations coincide with the needs of transporting goods in the final phase. They pick up the goods in shops or micro-hubs and transport them in their vehicles. For that, they receive appropriate compensation. In this way, the transporter can achieve lower delivery prices and fast delivery. Given that amateurs appear here as participants, prior and constant verification of their reliability is necessary. The driver applies for a job by using specialized

platforms⁶. There are different ways, including video interviews, for initial checks. During the engagement, the recipients evaluate the drivers after the delivery of the shipment. That allows a higher level of reliability to be achieved. The most suitable carriers for each delivery are selected using appropriate algorithms. Companies that organize this kind of delivery system usually provide insurance for packages. (Hanzlik, 2015) Some platforms allow the sender to choose among different modes of transportation: commuter, motorcycle, and vehicle. The first one can be slower than the others, but it is the cheapest (Abudheen, 2019). With its potential, crowd-shipping may soon become a significant factor in the sharing economy. They can be a good chance for SMEs to reduce logistics costs and improve logistics efficiency. However, this mode of transportation is not always reliable because it is frequently unavailable. Several factors need to come together. There should be a suitable driver with an appropriate vehicle in the vicinity of the place from which the shipment is to be picked up. Also, the driver's route should coincide with the required for the shipment delivery at the specific moment. Significant driver and vehicle base increases could increase the system's reliability. Mittal et al (Mittal, Marusak, Krejci, Sadeghiamirshahidi, & Rogers, 2022) evaluated crowd-shipping platforms to find how they are suitable for SMEs. They requested pro-forma invoices for delivery service based on the shipping requirements that two agriculture-based SMEs in Texas use in their practice.

As mentioned, smart cities can help transporters to organize intelligent transportation systems for last-mile delivery by providing appropriate data in real time. The number and position of vehicles used for delivery vary over time, so it is reasonable to say that fleet networking involves vehicular ad hoc networks (VANETs). In smart cities, vehicular networking is a crucial component of intelligent transportation systems. The obtained data enable the creation of an 'Internet of vehicles'. If VANETs optimization is successful, the system benefits can improve last-mile delivery in urban and suburban areas. But system optimization brings with it numerous challenges. The problem is even more pronounced because it must be solved in real time

⁵ Gurobi Optimization is a decision intelligence technology for optimal decision-making.

⁶ Some of the platforms are Peer and PiggyBee.

and an uncertain and dynamic environment. In the paper (Peyman, et al., 2023 Jan), one such simulation was performed on the example of Barcelona using data downloaded from Open Data Barcelona. The results showed that the constructive heuristic outperforms the random scenario in the customer data platform combined with vehicular networks. Better results are achieved in shortening the distance between facilities with meeting capacity requirements using the fewest facilities (Peyman, et al., 2023 Jan).

Besides named smart-city technologies, last-mile delivery solutions use technologies such as drones, autonomous vehicles, and intelligent lockers to speed up the last leg of the delivery process. We will discuss it in the next subchapters.

At the end of this subchapter, we can conclude that there is an interconnection between last-mile delivery and smart cities.

4 CONCLUSIONS

Life in big cities brings challenges for both the population and those who need to provide residents with favorable conditions for living and working. The situation is complicated because the cities were designed in different conditions than today. Hardly any big city has the projected capacities for the current number of inhabitants and the current standard of living. Therefore, cities must try to become "smart" and adapt to the new criteria. The problem is that these criteria also change over time, so constant adjustment and making projections of future development are necessary. One of the problems faced by smart city creation is logistics, more precisely, last-mile delivery. Usually, logistics centers are on the outskirts of cities, and from there, merchandise should be transported via micro-hubs or directly to the customer. Although last-mile delivery is the same as other logistics in terms of principles, due to the conditions in which it takes place and the set requirements it has its specificities. The main differences are in the number and size of shipments and the number of recipients. That highly affects the choice of delivery method, the required number and size of delivery vehicles, the required number of drivers and supporting staff, the choice of optimal vehicle paths, communication with the recipient of the shipment to reduce the risk of shipments non-delivery and,

ultimately, the cost of delivery. Last-mile delivery average costs are higher than costs in the rest of the supply chain.

The accuracy and quality of last-mile delivery affect the overall image that the customer acquires in doing business with the seller.

Customers expect delivery on the same day or at the end of the next day, on time and in good condition, without damage, and in the agreed quantity.

It is a challenge for all participants in the logistics chain. Technology can solve many problems, but people remain the most important. They should come up with models that will allow the customer to be satisfied. Blockchain technology is one of the promising technologies. It deserves great attention and high expectations. Blockchain technology allows every participant in the supply chain and customer to receive information about the goods and the shipment location in real-time without fraud. Information, once linked to the chain, cannot be changed. Only new data can be entered. With more links in the chain, fraud becomes more difficult, if not impossible. We recommend different private blockchains for different needs. That enables higher speed in entering new data and less need to include those who are objectively not interested in what is in the chain. The Ethereum-based platforms have proven to be stable and fast enough for many participants. Blockchain technology will be particularly effective in the automated delivery of goods and synergy with the IoT. The share of manual work will be reduced significantly, and thus the delivery cost. When automating delivery, the use of drones will bring additional benefits. Greater expectations are from ground drones that move along roads, but UAVs also have a perspective, especially in the delivery outside the city due to the reduced risk of damage due to the possible fall of the drone. There is still no universal legal regulation related to drones. It represents a significant limitation for drone use.

The results of the analysis from subchapter 3.2 reject the null hypothesis $H_{0,A}$ that "There is no correlation between logistics service quality and smart-city technologies" and confirm the alternative hypothesis $H_{a,A1}$, according to which there are cases where "there is a correlation

between city logistics service quality and smart-city technologies.”

The results of the analysis from subchapter 3.3 also reject the null hypothesis $H_{0,A}$ and confirm the

alternative hypothesis $H_{a,A2}$, that “there is a correlation between city last-mile delivery quality and smart-city technologies”.

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