Smarty city with green last mail delivery

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Abstract

This paper explores the possibilities of organizing sustainable last-mile delivery in smart cities. A smart city is a place where traditional networks and services become more efficient by using digital solutions for the benefit of its residents and businesses. Delivering goods to residents is a significant challenge in smart cities. With the development of e-commerce, which has been further boosted by the COVID-19 pandemic, there has been an evident increase in shipments, which further stimulates the implementation of new solutions to develop green last-mile delivery while meeting the service quality needs of users. Montenegro is taken as a case study. Montenegro keeps pace with technological development and thus the need to define a strategy for the development of smart cities, which includes mobility. The basis for smart mobility is information and communication technologies that currently play a crucial role in mobility, and this paper focuses on a smaller segment of mobility that encompasses the synergy of ICT technologies and postal services to develop smart cities. The paper will focus on calculating the difference in harmful gas emissions by implementing parcel lockers in dense urban areas of Montenegro.

Keywords: *last mile delivery, parcel lockers, Sustainable and smart delivery, smart city*

1 Smart city

When we talk about a smart city, we come across a very large number of definitions. What is common to all definitions is that the application of information - communication technologies (ICT) and data processing serves as a mean of solving economic, social, and environmental challenges in the city. There are more sources of innovation and systems available in the world today than ever before. The development of 5G networks and data collection has opened up new opportunities for improving the quality of life. Using the overall progress of technology, especially ICT, as well as its constant improvements, the development of a smart city should provide relevant scenarios for the life of citizens with the necessary quality and simplicity in overcrowded urban environments. The development of smart cities is expected to improve economic growth and development to build a clean and sustainable environment, increase income for all, provide support to the disadvantaged and make the management of city services more transparent.

1.1. Smart city – Montenegro

Geographical position, climate conditions and characteristics of its area, natural resources and their distribution make Montenegro an exceptional European country in many ways. Montenegro is on the path towards European integration and joining the European Union, but to keep up with developed European countries and direct development towards increasing the quality of life of citizens and the efficiency of state and local services, it is necessary to define a Smart City strategy. By implementing the Information Society Development Strategy, Smart Specialization Strategy, and Sustainable Development Strategy, significant progress is being made towards achieving these goals. However, to properly define the mission, vision,

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and goals of a smart city, it is necessary to incorporate this document with existing strategies and their objectives. The aspiration of a smart city is related to the transformation and improvement of the quality life of citizens, efficient management and development of local self-government, sustainable management of natural resources and energy. The pandemic that hit the world presented and accelerated the desire to preserve the environment, through the reduction of the use of pollutants, including motor vehicles. In the past three years, there has been a significant increase in last-mile delivery, as people increasingly bought products online and the ecosystem had a good and fast response to all requests, this trend is still present today to a large extent, with upgrades and constant improvements it will increase degree of sustainability, mobility as well as economic efficiency and thereby fulfil some of the main aspirations of a smart city.

1.1 Sustainable and Smart cities

Preservation of natural heritage is a big challenge for cities in the 2nd century. Sudden urbanization, the need for additional facilities, the increase in the movement of people and goods make it difficult to protect the natural wealth of cities. The smart and strategically oriented development of infrastructure as well as the application of new technologies can significantly mitigate the negative effects on the environment. Smart cities transform the environment into their infrastructure, enabling a better quality of life for the population in the cities and increasing the energy efficiency of the infrastructure [5].

2 Urban mobility

Urban mobility is one of the most relevant factors when the subject is sustainability. The Sustainable Urban Mobility Plan (SUMP) is a strategic plan that builds on existing planning practice and considers integration, participation, and evaluation principles in order to meet the mobility needs of city dwellers, now and in the future. and provided a better quality of life in cities and their surroundings. The goal of the Plan for Sustainable Mobility in Cities is to create a sustainable transport system in cities by:

• ensuring availability of jobs and services to everyone

• safety and security improvements

• reduction of pollution, emission of greenhouse gases and energy consumption

• increasing efficiency and economy in the transportation of people and goods

• increase in the attractiveness and quality of the urban environment.

2.1 Sustainable and smart mobility

The European Commission adopted the Sustainable and Smart Mobility Strategy - – putting European transport on track for the future in December 2020 [6]. This strategy laid the foundations for how the EU's transport system can achieve its green and digital. The strategy is structured around three key objectives: to make the European transport system sustainable, smart, and resilient.

(1) Sustainable mobility: A clear path is needed to achieve a 90% reduction in transport-related greenhouse gas emissions by 2050 to ensure that the EU becomes the first climate neutral continent by 2050 as called for by the European Green Plan. Today, transport accounts for a quarter of the total greenhouse gas emissions in the European Union.

Digital mobility: Digitization will become an indispensable driver for the modernization of the entire system, making it invisible and more efficient, while further reducing emissions. Europe also needs to use digitization and automation to further increase levels of safety, efficiency, reliability, and comfort, thus maintaining the European Union's leadership in transport equipment manufacturing and services and improving our global competitiveness. In this way, research, and testing before introduction through funding instruments such as Horizon Europe and the Connecting Europe Facility play a key role.

Resilient mobility: The coronavirus pandemic has shown how important our single market and the social, health and economic costs are when the free movement of people and goods is severely or even completely restricted. Preservation of supply chains and a coordinated European approach to connectivity and transport activities are key to overcoming any crisis and strengthening the strategic autonomy and resilience of the European Union. The goals are to direct the necessary investments in the recovery of infrastructure and fleets to modernize and green the sector and to strengthen our single European market. Also, the elements that will be insisted on is a fair transition for users and workers, as well as the need for mobility to remain safe.

Specific goals set by the Strategy for 2030:

By 2030:

- at least 30 million zero-emission vehicles will be in operation on European roads.
- 100 European cities will be climate neutral.
- high-speed rail traffic will double.
- scheduled collective travel of under 500 km should be carbon neutral within the EU.
- automated mobility will be deployed at large scale.
- zero-emission vessels will become ready for market.

By 2035.:

- zero-emission large aircraft will become ready for market.

2050.:

- nearly all cars, vans, buses as well as new heavy-duty vehicles will be zero emission.
- rail freight traffic will double.
- high-speed rail traffic will triple.
- the multimodal Trans-European Transport Network (TEN-T) equipped for sustainable and smart transport with high-speed connectivity will be operational for the comprehensive network.

Given that postal traffic and delivery (last mail delivery) of parcels is an integral part of traffic primarily by road (because most parcels at the European level are transported by road, it is necessary to harmonize the strategy of the development of postal activity with the Strategy for sustainable and smart mobility. Therefore, one of important topics of smart city organizing sustainable processes of urban logistics last-mile logistics (micro-level) The key challenges faced by the organizers of last-mail delivery in urban areas are the following:

1. İncreased urbanization (restrictions to mobility in most urban areas)

2. Booming in e-commerce (problems in capacity)

3. Changing customer expectations (demand for a short delivery time, high service quality, and more free shipping)

4. Rising debates over environmental issues (more conscious city actors toward CO2 emissions, noise pollution, and visual intrusion)

5. Impact on traffic congestion (the high number of delivery vehicles on the road)

6. Deficiencies in urban planning for logistics operations (lack of loading and unloading space in inner-urban areas)

7. High delivery cost per parcel (inefficiencies in operations especially for last-mile delivery)

8. Rising trends through multi-channel distribution (a need for adding value-added business models)

3 Sustainable last mail delivery postal items

The postal sector is committed to serving its customers while mitigating its environmental and social impacts worldwide. As operators of over half a million vehicles, thousands of buildings, and employing a workforce of more than 1.3 million, posts have considerable opportunities to make positive contributions to both people and the planet.

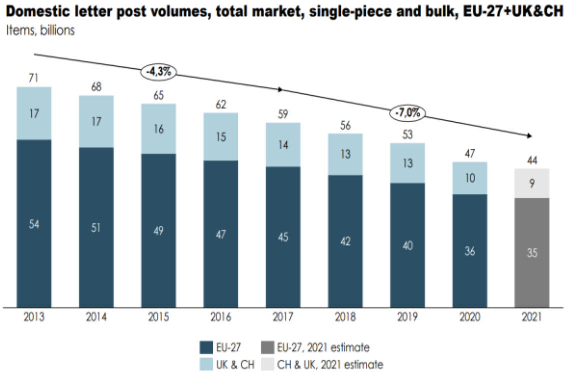

Fig. 1: Domestic letter post volumes, total market, single-piece and bulk - EU countries [7]

Changes in the product structure [Fig.1, Fig.2], less letters increase parcels, create challenges for postal operators to reduce their environmental footprint.

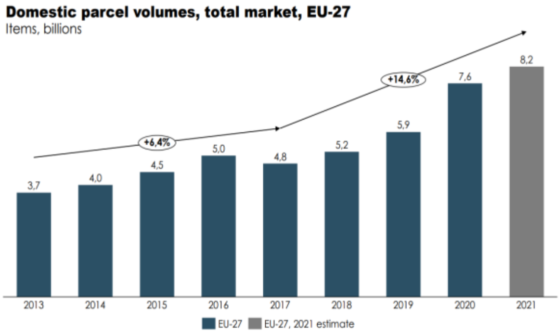

Fig. 2.: Domestic parcel volumes, total market – EU countries [7]

Postal operators' product mix is changing – the relative importance of parcel delivery is increasing. This has important implications for postal operators' environmental footprint because parcel delivery requires significantly more logistical and transportation capacity than letters. The carbon emissions per parcel are greater than the carbon emissions per letter.

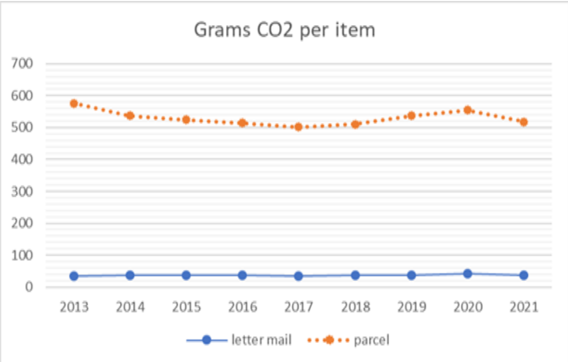

Fig 3: CO2 emissions from parcel and letter delivery 2013–2021 [8]

Postal operators will focus mainly on emissions generated by buildings and transportation, which respectively account for 45 and 55% of their total emissions. By 2030, posts collectively aim to have 50% of their fleet as alternative fuel vehicles (against 22% in 2020), of which 25% of electric vehicles (against 16% in 2020) and 75% of their energy consumed, generated from renewable sources (against 33% in 2020) [7]. In line with their alignment with the UN Sustainability Development goals, postal commitment also goes beyond CO2 emissions. By 2030, they collectively commit to have 50% of sold packaging reusable, recyclable, or compostable. Environmental Measurement and Monitoring System covers seven categories which relate to five SDGs where posts could have the most positive impact. These include Health and Safety, Learning and Development, Resource Efficiency, Air Quality, Circular Economy, Sustainable Procurement and Climate Change.

According to the data, it is evident that there is an increase in CO2 emissions per package, which is due to several reasons:

- The packages are larger in size, hence the number of packages that fit in a vehicle is reduced.
- An increasing number of users are ordering online, which leads to a higher number of stops for individual package deliveries.
- A significant number of packages still cannot be delivered on the first attempt (for Montenegro, the number of packages that are successfully delivered on the first attempt is between 80-90%).

3.1 The impact of green delivery on CO2 emissions

One way to reduce CO2 emissions in urban areas is to install parcel lockers for last mail delivery. Parcel lockers are one of the options that postal operators use to optimize processes and reduce CO2 emissions. To make parcel lockers contribute to reducing CO2 emissions, attention needs to be paid to their location, as otherwise, they could further stimulate CO2 emissions. However, for parcel lockers to be acceptable as a CO2 reduction element, it is also important that users who come to the parcel locker point use environmentally friendly means (by walking or cycling) [9]. Analysis of previous studies has determined an acceptable distance for walking. As shown in Figure 4 - the function for the transportation mode of walking drops the fastest, given the maximum value of the distance that people are willing to walk (up to 1km). This approach can also be applied to determine the location of parcel lockers in urban areas. The distance to the parcel locker up to 1 km [10] is acceptable for users to walk.

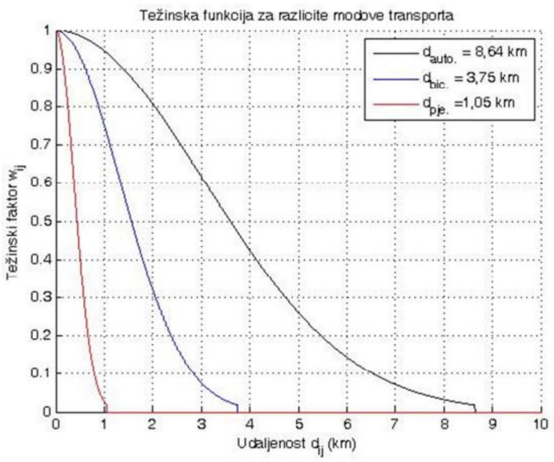

Fig 4: Representation of weight values in different transportation modes [10]

It can be concluded that if the distance from the user to the parcel locker is greater than 1 km, there is a high probability that the user would not walk to the locker as a mode of transportation from home to the locker, but instead use another mode of transportation (bike, public transport, or personal vehicle). According to research [11], the acceptable distance for users to walk to a Parcel Locker is 700 meters, or 3 minutes. Since we are considering a smaller urban environment, we observed a potential distance of up to 800 meters. If a user were to use a personal vehicle as a mode of transportation in these cases, the CO2 emissions would be multiplied compared to the CO2 emissions that the postal service provider would produce if they attempted to deliver to the user's home [9].

In conclusion, parcel lockers as points of collection or delivery in smart cities can contribute to reducing CO2 emissions if located at appropriate locations.

3.2 An example of a smart city organization with green delivery in Montenegro

For this paper, an analysis of express mail delivery by Montenegro Post in the city of Budva was conducted. Budva is a densely populated urban area with a total population of 10,918 [12] residents living in an area of approximately 4.2 square kilometres.

In addition, the criterion for determining the required number of parcel lockers was used as an additional tool [13]. The criterion states that the universal postal service operator provides a network of public postal services such that one branch operates on average:

- in an area of up to 100 km2 or

- for up to 5000 residents.

Therefore, we used the same criterion for determining the number of parcel lockers as for determining the number of postal services. Based on this criterion, we concluded that two parcel lockers were sufficient for the number of residents.

An additional task was to determine their locations. The Location Set Covering Problem (LSCP) model was used to define the locations of the parcel lockers.The Location Set Covering Problem is described by Toregas et al. (1971). Therefore the LSCP model was proprosed whereby *the minimum number of facilities determined and locaten so that every demand area is covered within a predefined maximal service distance or time (Church and Murray, 2018) [14]*

The set covering location problem (SCLP) can be formulated as:

Minimize $\sum_{j \in J} \mathrm{Y}_j$ (1)

Subject to: $\sum_{j \in N_i}^{n} \mathrm{Y}_j \geq 1 \quad \forall_i \in I$ (2)

$Y_j \in 0,1 \ \forall_j \in J$ (3)

Where:

i = index of demand points/areas/objects in set I

j = index of potential facility sites in set J

S – maximal acceptable service distance or time standard

d_{ij} – shortest distance between nodes I and j

N_i ={j | $d_{ij} \leq$ S} - the set of all candidate locations that can cover demand point i and the following decision variable

$$Y_j = \begin{cases} 1, & if\ a\ facility\ is\ located\ at\ mode\ j \\ 0, & otherwise \end{cases}$$

Determining the location in our example of a parcel locker represents solving specific location problems for covering customers. It is often used in determining locations for emergency services such as police and fire stations, ambulances, but it is also encountered in literature as a method for determining the location of post offices [16]. They must cover as many people as possible while keeping servicing costs as low as possible.

In practice, the costs of serving a client are usually directly proportional to the distance between the client and the facilities. However, in this study, we track the CO2 emissions per parcel in the last mile phase in urban environments - the city of Budva. The primary objective of this study was to select locations for service facilities so that as many potential clients as possible would be covered. Many models of this problem have been defined and solved, but one of the most important is the maximal covering location problem (MCLP).

To determine the location of parcel lockers, we used criteria established in [10], according to which the expected distance that a user would walk without using any means of transportation is up to 1 km. In this way, we divided the city of Budva into 12 squares, each with a diagonal of 800m. In this way, we obtained 20 potential points for the location of parcel lockers (Fig 5), based on which we observed the distances between points that users would walk in case the distance was up to 1 km.

We eliminated points on the outskirts of the city where there are no residential buildings (points 1,2,4,5,13,15,16,17, 19, and 20). In the next step, we obtained a 20 x 20 matrix - the columns with the highest sum represent a potential location for placing parcel lockers.

Table 1: Covering matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0		0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	1	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0
7	0	0	1	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0
8	0	0	1	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0
9	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	0
10	0	0	0	0	0	1	1	0	0	1	1	0	0	1	0	0	0	0	0	0
11	0	0	0	0	0	1	1	1	0	1	1	1	0	1	0	0	0	0	0	0
12	0	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0		0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	0		0	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	4	0	0	6	**7**	5	3	6	7	4	0	**5**	0	0	0	1	0	0

The following step resulted in obtaining two key points for the location of the parcel machines:

the first point - point 14 in the city centre (where banks, restaurants, and the beach, as well as the main post office, are located),

the second point is point 7 in the dense residential area of the Babilonija settlement.

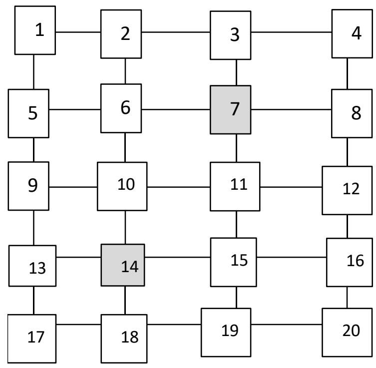

Fig 5: Nodes-candidates for the parcel locker

A potential point of consideration was also point 11, however, considering that there is already a post office at point 14, and the goal is to reduce CO2 emissions, by choosing to point 14 as the location for the parcel machine, we achieved greater savings in reducing CO2 emissions.

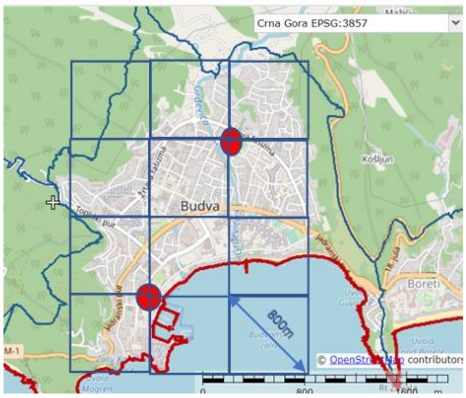

Fig. 6: Proposed location for a parcel locker in the city of Budva

4 Conclusion

By analysing data from the Montenegro Post about package delivery in the city of Budva, it was determined that the vehicle delivering packages in the city of Budva on average travels 45km per day. If package delivery were to be carried out exclusively via the mentioned 2 package stations, then the express delivery vehicle would cover between 1.5 km – 2 km per day (depending on traffic density primarily in summer months). In this paper, the SCLP method is presented as an effective tool that can be used for scheduling parcel lockers and access points as presented in [16].

Emissions from transport account for one quarter of the EU's greenhouse gas emissions. To achieve climate neutrality, the European Green Deal calls for a 90% reduction in greenhouse gas emissions from transport by 2050 (EEA, 2019). Regulation (EU) 2019/631 (EU, 2019) sets a fleet-wide target of 147g CO2/km for the years 2020-2024, and stricter fleet-wide targets for 2025 and 2030. Following a steady decline between 2012 and 2017 and a slight increase between 2017 and 2019, 2020 saw average specific CO2 emissions of newly registered light commercial vehicles fall to 155.0g CO2/km – a 2% decrease in comparison to 2019.

For the purposes of this paper, the average emissions of a delivery vehicle of 150g CO2/km were considered. If we were to analyse CO2 savings in the example of the city of Budva, for last mile delivery of packages through package machines - over the course of one year, it would amount to 1.7T CO2, if all citizens would come to collect their packages on foot or would not travel additional kilometres to retrieve their shipment. In this way, a 95% reduction in CO2 emissions per package for the last mile delivery would be achieved compared to the current method of last mile package delivery in the city of Budva.

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