CONCEPT OF USING ELECTRIC CARS IN THE IMPLEMENTATION OF "LAST MILE" DELIVERIES

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Introduction/background: The article is devoted to the possibility of "last mile" deliveries by electric cars with a permissible total weight of up to 3.5 tons.
Aim of the paper: The aim of this article is to determine whether, with the technology currently available from electric car manufacturers, it is possible to use these vehicles for "last mile" deliveries.
Materials and methods: The article contains a literature study of industry publications and the most important legal acts in European Union and in Poland. At the same time, the available issues in the field of "last mile" deliveries and the currently available technology of electric cars were analyzed.
Results and conclusions: As a result of research based on the adopted assumptions for the implementation of "last mile" deliveries and the technical parameters of the currently available electric vans, the article presents a newly developed simplified algorithm showing the relationships between the time and number of unloading in relation to the length of the delivery routes. At the same time showing that the currently available technology of electric cars allows for the implementation of this process with their use.

Keywords: last mile deliveries, electric vans, urban logistics, energy storage, clean energy.

1. Introduction

Last mile deliveries pose an increasing challenge to logistics, which has to meet increasingly demanding customers who expect almost immediate delivery. Due to the increasingly deteriorating condition of the natural environment, transport needs, especially in intensively urbanized areas, must be met while reducing the level of nuisance related to the emission of pollutants and noise. On a daily basis, solutions such as electric delivery vans, energy storage and renewable sources available, often at the place of their demand. Currently, every major car manufacturer has already introduced electric cars to its production profile and at the same time, we can observe very intensively researching and developing of fast charging and storage of electricity technology.

In the presented concept, the electric car, apart from the goods intended for transport, also charges its electricity storage in the transhipment city terminal. Then it delivers the goods to the final customers or the so-called last mile points such as "parcel lockers" on its route, after which it returns to its departure or other suitable city transhipment terminal or logistics center.

Logistics in the era of the growing global problem of accelerating greenhouse processes caused by the increase in environmental pollution. Growing greenhouse gas emissions and the constant exploitation of non-renewable energy resources can significantly accelerate these processes. It seems that logistics is one of the key disciplines that can contribute not only to the inhibition of the above-mentioned harmful effects on the environment, but through integration with modern technologies from various fields, lead to an increase in the pace of work and research aimed at almost complete stopping or reversing unfavorable trends currently observed on a global scale.

The broadly understood logistics through transport and related infrastructure has a significant impact on the development of individual regions. The most urbanized regions are most affected by the problem of environmental pollution, including air pollution. Due to the fact that the end recipients of the final products, statistically, most often live in the most urbanized areas, it is there that the increase in the intensity of logistics processes is an inevitable phenomenon. This is especially true of both developed and developing areas. Naturally, the more urbanized an area, the more vulnerable it is to negative influences caused by transport, therefore it seems necessary to optimize logistics processes related to transport.

2. Theoretical background

The "Strategy for Sustainable Transport Development until 2030" shows that in some urban areas the traffic of cars and trucks should be limited, inter alia, by building ring roads. The infrastructure for alternative fuels will also be developed to ensure that vehicles powered by such fuel can be used more widely in urban traffic. The use of zero-emission vehicles in last mile connections for urban freight services will be promoted. The research carried out as part of this study concerns the flow of goods as part of the last stage of the delivery of goods and materials carried out via a logistics network operating in the urbanized area, taking into account technologies using renewable energy sources.

Due to the fact that the most urbanized areas are most often both the source and the recipient of the goods sent, the problems of distribution and transport in metropolitan areas related to the problems of the so-called Last mile.

Detailed description of the term "last mile" presented by (Mantey, 2017) is one of most often used in logistics to refer to goods transported from the distribution center that is closest to the final recipient. The name itself suggests a distance of exactly one mile, but in fact it is often from several to several dozen miles.

Difficulties in the implementation of the so-called logistics "last mile" result from the ever-increasing density, as we reading in (Branch, 2018) which we observe in urban areas, as a result of which we are dealing with a continuous increase in both the final collection points and the complication of the delivery planning process itself. In addition to urbanized areas, of course, we observe a very high intensity of road traffic, which has a negative impact on the delivery time. In addition, last mile transport issues are undoubtedly problems of sustainable transport of goods in the city's logistics system.

The ways of transporting presented by (Civitas, 2015) goods in the city are becoming an increasingly important issue, as no city is able to meet the consumption needs of its inhabitants without having to import goods from outside the city's logistics system. Last mile logistics in the supply chain becomes an important element.

As we reading in (Klich, 2018) the operators of the last mile are usually the suppliers of letters, parcels and food on the phone. The research conducted for e-Commers Polska shows that the most frequently chosen form of delivery is courier transport directly to the address indicated by the customer.

Due to the necessity to build relatively short shipping sections and the possibility of direct delivery of goods to collection points, the main means of transport used in last mile logistics is a delivery truck. (Szołtysek, 2005) notes that the problem of meeting the transport needs of goods in large cities and agglomerations is difficult.

As (Cichosz, Pluta-Zaręba, 2018) writes the investment outlays on IT systems, infrastructure and people that would have to be incurred in order to improve or re-create a distribution system that would allow entrepreneurs operating in a virtual space to reach a dispersed customer base, would be enormous. That is why many enterprises entrust their "last mile" service to specialized companies.

The condition of the natural environment in cities (Tundys, 2013) is extremely important and requires both maintaining it at an undeteriorated level and striving to improve it. This means that environmental aspects must always be taken into account when designing an urban logistics concept. These assumptions are intensively supported by European Union directives, which we can see in a significant number of EU projects aimed at meeting the relevant environmental requirements in cities.

The essence of the problem is raised by Directive 2009/33/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of clean and energy-efficient road transport vehicles. It requires contracting authorities, contracting entities and certain operators to take into account the energy factor and environmental impacts during the entire life cycle of the vehicle, including energy consumption and emissions of CO2 and certain pollutants, when purchasing road transport vehicles, in order to promote and stimulate a clean market and energy-efficient vehicles, increasing the share of the transport sector in Community environmental, climate and energy policies.

Another example of EU policy aimed at clean urban transport is Directive 2014/94/EU of the European Parliament and of the Council of October 22, 2014. on the development of alternative fuels infrastructure. The aim of which is to establish a common framework for measures relating to the development of alternative fuels infrastructure in the European Union in order to minimize dependence on oil and reduce the environmental impact of transport. This Directive lays down minimum requirements for the development of alternative fuels infrastructure, including recharging points for electric vehicles and refueling points for natural gas (LNG and CNG) and hydrogen, to be implemented through the national policy frameworks of the Member States, and common technical specifications for such points. charging and refueling, and sets out user information requirements. One of the most noticeable projects is the project of introducing environmental zones in cities. Areas in cities to which only well-defined and marked vehicles have access. Germany has very advanced projects in this regard, which introduced the so-called "Green Zones" referred to as Umweltzone. Only such cars and trucks are allowed to enter these zones, which are marked with a special badge, the type of which depends on the exhaust emission standards met by these vehicles. When entering a given zone without a badge, drivers can expect a high penalties.

In Poland, work is also underway on the inevitable introduction of the so-called "green zones", which is the subject of work on the amendment to the act of January 11, 2018 on electromobility and alternative fuels. According to the new assumptions presented in 2021, the obligation to introduce zones will result from the results of the inspection by the Chief Inspector of Environmental Protection, which will show that the permissible average annual level of air pollution with nitrogen dioxide (NO2) is exceeded. However, in this assumption, the provisions on the permission to enter the zones with combustion vehicles that meet certain Euro standards have disappeared, which can clearly mean that only "zero-emission" cars are allowed.

Undoubtedly, the factor contributing to the growing importance of these problems is the fact of the constantly progressing urbanization, which affects urban logistics by increasing both the number of urban units and the number of inhabitants and their population density in a given area. According to data presented by the United Nations, the degree of urbanization in Europe is currently as high as (74%), while in North America this rate is as high as 84%. According to the data presented by the polish Central Statistical Office (GUS), in the last decade the urbanization index for Poland oscillated in the area of 60%, of which in the Śląskie Region it exceeded the average for Europe, ranging from 76% to even 78%.

The degree of urbanization is quite accurately reflected by the DEGURBA indicator used to classify local administrative units into three groups of units: "cities", "small towns or suburbs" and "areas rural". This classification is based on measuring the population density and geographic continuity (neighborhood) in grid cells with a resolution level of 1 km^2 (kilometer grid). For this purpose, a grid typology with a resolution level of 1 km^2 (kilometer grid) is used (this typology groups the grid cells into "urban centers", "urban clusters" and "rural grid cells"). The three types of local administrative units (LAUs) are defined as follows:

- cities (densely populated areas): local administrative units where at least 50% of the population lives in 'urban centers',
- small towns and suburbs (moderately populated areas): local administrative units where less than 50% of the population lives in "urban centers" and at the same time less than 50% of the population lives in "rural grid cells",
- rural areas (sparsely populated areas): local administrative units where more than 50% of the population lives in 'rural grid cells.

As we can see in Figure 1, the Śląskie and the area of the Upper Silesian Economic Area is, according to the DEGURBA indicator, the largest and most urbanized area of Poland.

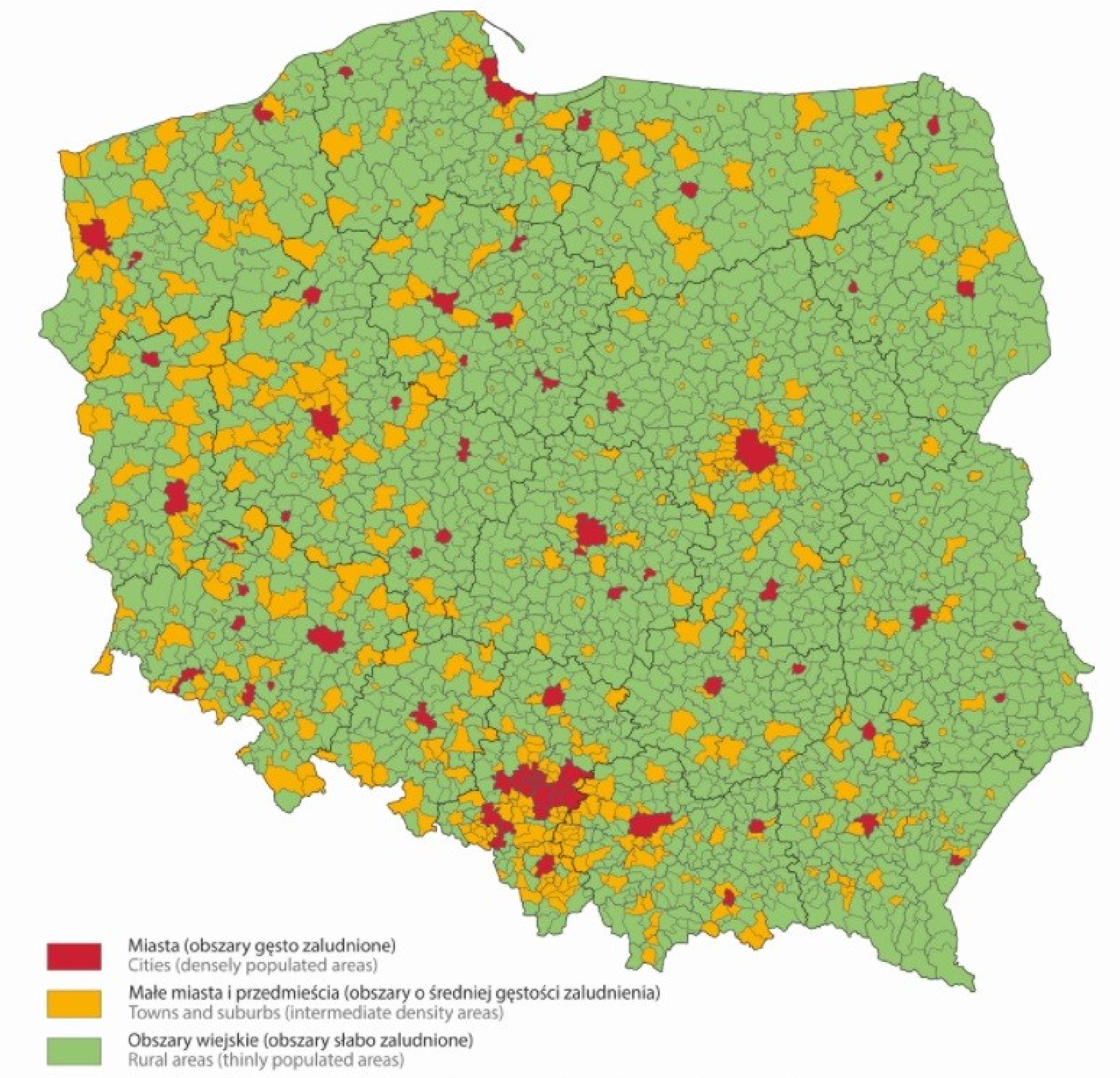

Figure 1. Types of communes in Poland according to the degree of urbanization in 2018. Source: https://stat.gov.pl/statystyka-regionalna/jednostki-terytorialne/unijne-typologie-terytorialne-tercet/stopien-urbanizacji-degurba/.

3. Method

To answer the question whether electric cars can be used in order to implement the last mile in the most urbanized areas we have to check possibility of electrical vehicles in delivery of the last mile. The technical data of exemplary producers of electric cars weighing up to 3.5 tons, which can be used for the implementation of "last mile" transport, was analyzed and an algorithm was proposed. It was taken into account input data such as total working time, the total driving time, average speed in an urbanized area, loading time, number of loads, number of unloading, average unloading time and total time without driving. Above information allow to calculate the average number of kilometers traveled, which allows to answer the above question.

Presented algorithm can only be used for an initial answer to the question whether a given vehicle is capable of performing the tasks set for it. Due to the fact that it takes into account many factors that may affect the results of calculations, such as the topography of a given area, the actual available energy depending, for example, on discharge time as a function of temperature, drive efficiency depending on the driving culture of the driver (acceleration and braking). The article presents, however, the assumed computational experiments and presents the obtained results.

Here, the basic assumptions adopted during the consideration of the possibility of using the concept of using electric cars for the implementation of transport tasks, the so-called Last mile. It was assumed that the typical total working time of a delivery vehicle operating as part of the delivery of goods in an urbanized area is eight hours. In addition, it was assumed that the average time of goods release, in which the vehicle is not working, i.e. it does not consume the previously stored electricity, is 10 minutes. The vehicle is loaded with a loading center which is at the same time an area with available infrastructure that allows for charging the vehicle both in real time, using the energy available from the use of renewable sources and traditional network sources. In addition, it was assumed that the loading time is an average of 30 minutes in a daily cycle, while the average vehicle speed during the delivery will never exceed 50 km/h, which is also conditioned by the restrictions applicable in built-up areas as to the maximum permissible speed.

Example of the electric vehicle range characteristics depending on the constant speed with or without the use of air conditioning and heating we can see in Figure 2.

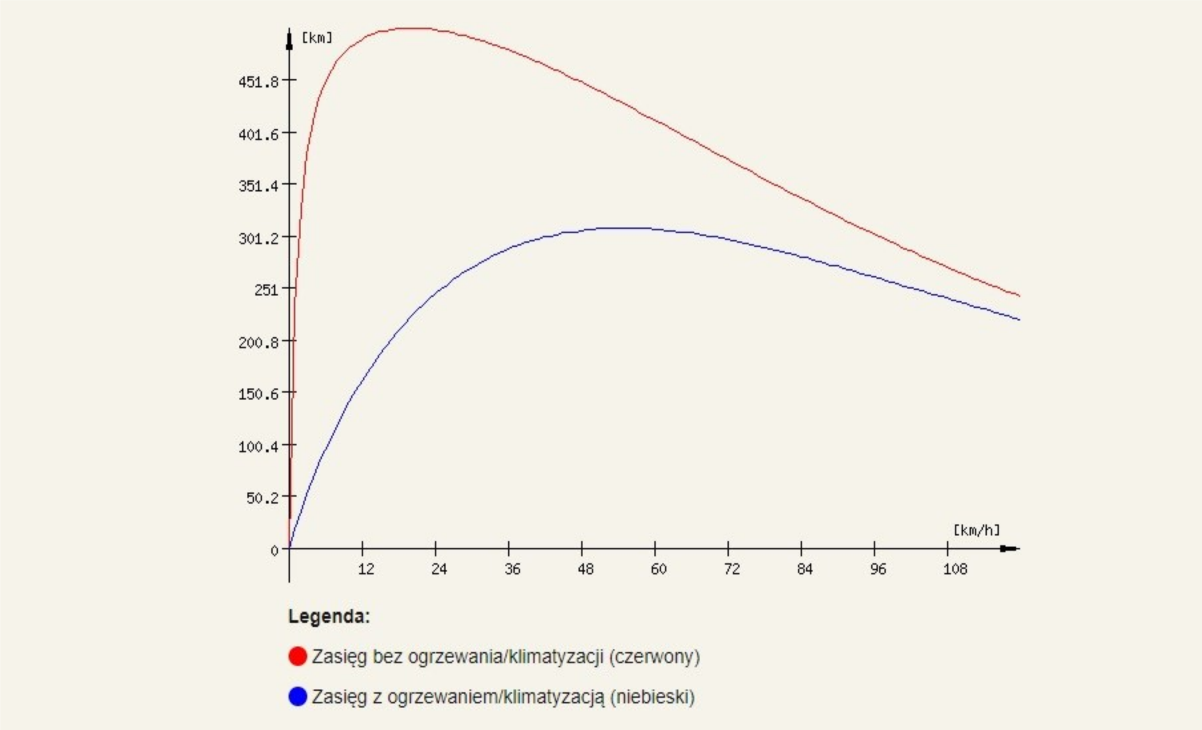

Figure 2. Example characteristics of the range of an electric vehicle in speed function source. Source: https://samochodyelektryczne.org.

The assumptions of the model, the purpose of which is to answer the question of how many stopping points and what time of stoppage is permissible with the currently available electric car technology in the context of last mile deliveries, are presented in Table 1 below.

Table 1.
Parameters and function determining the length of the route

Parameter	Function
Tjs	Tc – Tr
Tr	(Ir * Trs) + Tz
S	(Tjs/60)*Vsr

Note: See Description of variables in table 2.

Source: own study.

In the presented model, the goal is to obtain information on the maximum length of the route that an electric car can cover when performing tasks related to the implementation of "last mile" transport in an urbanized area. Parameters were adopted in the form of constant and variable values, which are presented in Table 2.

Table 2.
Parameters taken into account in determining the length of the route

Parametr	Parameter description	Unit
Tc	total working time	[sec]
Tjś	average driver change/drive time [sec.]	[sec]
Vsr	average maximum speed of the vehicle	[km/h]
Tz	loading time	[sec]
Ir	number of unloading	[ilość]
Tr	downtime	[sec]
Trs	average unloading time	[sec]
S	kilometers traveled	[km]

Source: own study.

Below presented sample calculation in order to carry out the computational experiment, the technical data of some of the electric van cars available on the market, were adopted for the implementation of transport tasks in the area of the "last mile" and presented in Tabel 3.

Table 3.
Sample parameters of selected electrical motor vans

Model	e-NV2001	e Berlingo2	e-Partner3
Motor power KM	109	136	136
CapacitykWh	40	50	50
Range (WLTP) – Urban cycle distance km	301	285	275
Permissible total weight of the vehicle	2220	2 366	2 366

Source: https://www.motofakty.pl/artykul/peugeot-e-partner-citroen-e-berlingo-van-pierwsze-jazdy-wrazenia-dane-techniczne-i-ceny.html; https://ev-database.org/car/1546/Citroen-e-Berlingo-M-50-kWh; https://poland.nissannews.com/pl-PL/releases/release-426214151.

As we can observe, the information provided by the manufacturer confirms the assumptions presented in the characteristics of the electric vehicle range depending on the constant speed indicated in Figure 2 of this article. They directly show that in city mode the range of such a car oscillates around 300 km. In addition, we can see that the landing time with a standard 6.6 kW car charger is 7.5 hours, which should be fully enough to charge the vehicle even twice in the 8/24h operation mode.

It is necessary to include into account the changes in battery capacity with regard to temperature dropping, as we read in (Mazan, 2020) with a tendency to lose the capacity level at lower temperatures. Based on the results of the change in the capacity of the batteries used in electric cars we can see a strong influence of the ambient temperature on the capacity of the batteries up to 13% for a temperature of -30°C.

It should be noted that the number of hours a year in Poland when the temperature drops below -10°C during the day often does not exceed several dozen hours per season.

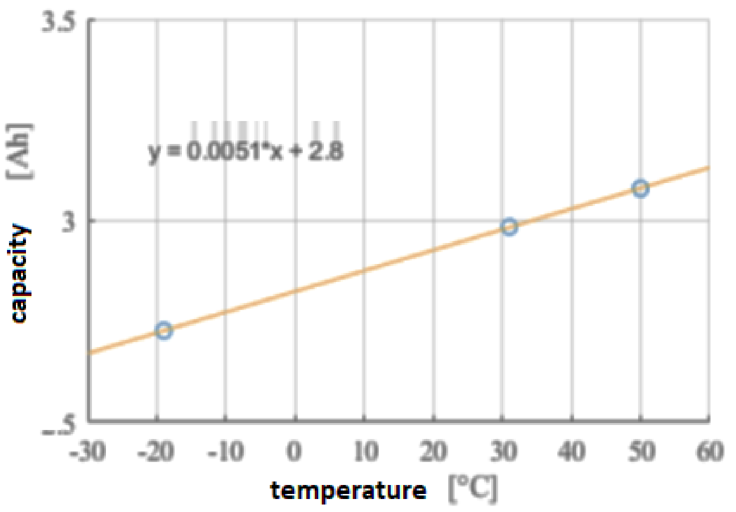

Figure 3. Dependence of lithium-ion battery capacity on temperature change. Source: Mazan B., Detka T. (2020). Eksperymentalne badanie wpływu temperatury ogniwa litowo-jonowego na pojemność i dokładność obliczeń stopnia naładowania. Napędy i sterowanie. Warszawa.

When analyzing the technical documentation of, for example, a Berlingo car in a mixed city cycle at -10°C, the vehicle's range drops from 285 to 215 km, which is a decrease of 24%.

Table 4 presents a selection of 10 sample data sets – the sets have different average loading times and standstill times. It was possible to obtain the optimal ranges for these two parameters, assuming that the maximum permissible route that an electric car can cover is 300 km/day. During the calculations, a large correlation was noticed between the average time of unloading and the number of unloading in the maximum length of the route.

Table 4.
Data of random different average loading times and unloading times

Average unloading time	Number of unloading	Average daily distance
3	30	300.00
4	22	301.67
5	18	300.00
6	15	300.00
7	12	305.00
8	11	301.67
9	10	300.00
10	9	300.00
11	8	301.67
12	7	305.00

Source: own study based on the assumption of 8 hours of vehicle operation and an average maximum speed of 60 km/h.

4. Results and conclusions

In above article presents the results obtained by means of a newly developed simplified algorithm determining the possibility of using electric cars depending on the number of kilometers that can be traveled on the one hand, and on the other hand, the number and duration of unloading occurring at that time. The obtained results can be treated as satisfactory due to the fact that they confirm the possibility of using electric cars to perform "last mile" transport tasks with certain assumptions and limitations resulting from the specificity of electric drive systems.

As (Czerwiński, 2005) writes, it is undoubtedly important here to take into account the problems faced by the automotive industry in connection with the increased demand for comprehensive management of energy resources (Dyczkowska, 2012). Analyzing road, rail and inland waterway transport for the transport of goods, the lowest consumption of energy resources and carbon dioxide is observed in rail transport, and the highest in road transport.

Conclusions: due to new restrictions in the field of pollutant emissions and the introduction of so-called ecological zones in city centers, to which only strictly defined and marked vehicles have access, it is necessary to analyze and revise the approach to deliveries at the most urbanized areas. After analyzing the problem, it can be concluded that, while maintaining the appropriate assumptions, it is possible to make last mile deliveries using electric cars already widely available on the market.

Acknowledgements

Sincere gratitude to Professor Katarzyna Dohn.

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