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EFFECTIVENESS OF DELIVERY TRANSPORTATION PROCESS WHILE USING ELECTRIC FREIGHT VEHICLE

The paper is devoted to determining the efficiency of the transport process for the delivery of confectionery products within the city. Comparing electric and diesel type of freight vehicles it was made conclusions about the advantages of choosing a mode of freight transport in Kharkiv.

Keywords: *city logistics, electric freight vehicle, route, transportation.*

Formulation of the problem

Urban freight transport (UFT) is important for transporting goods, especially confectionery that is in demand and needs special attention during transportation, but many negative sustainability impacts can influence on the process. The environmental impact of urban freight transport increases with population density and urban stagnation. According to experts from the leading German logistics company Deutsche Post DHL Group, there is a need for more efficient freight transport systems that not only take into account costs but also completely solve environmental problems [1]. In studies of European Commission in the field of logistics, urban freight traffic is more polluting than long distance transportation, due to the average lifetime of vehicles and the large numbers of short trips and stops. Freight traffic is about one quarter of CO_2 emissions from transport operations in cities [2]. One of the solutions to reduce negative impact, that becomes more popular nowadays, is electric freight vehicle (EFV). Unfortunately, there are not a lot of papers devoted to the evaluation of effectiveness of freight transportation by EFV in Ukraine despite the fact that there are huge environmental challenges existing in this country.

Analysis of recent research and publications

Implementation of EFVs in city logistics is connected with some advantages – lack of gaseous or solid pollutant emissions [3], lack of noise emissions, energy efficiency [4]. Paper [5] describes assessing the potential of EFV to reduce freight transport GHG emissions in France taking into account vehicle range and urban congestion. The results show that electrification of freight vehicles should be done in cities bigger than 100 000 inhabitants, because of high concentration CO_2. Using any type of fully electrically powered vehicle implies a significantly lower consumption cost and price of kWh comparing to any gasoline or diesel car [6-8]. Considering that more than 80% of the deliveries are of distances about 80-100 km in European urban areas, the use of EFV for city logistics operations could be a feasible option in operational terms [9, 10].

Two types of measures can be executed the electrification of urban freight traffic: regulation – a limitation of access to diesel (or to most pollutant) vehicles in specific zones (Low Emission Zone), a priority given to electric vehicles or an obligation to deliver by this type of vehicle [4]. The research [11] also shows differences between electric truck and diesel truck in delivery comparing the most relevant issues – energy use, emissions and energy cost. The consumption of the vehicle depends on the capacity of its battery and the type of driving, so it could be estimated that costs on electricity about 40% lower than that of internal combustion engines for the same distance. In article [12] considered positive and negative technological features «The FREVUE project», like an acute turning range, steering circle and improved visibility facilitate the maneuvering of the vehicles in dense city areas, charging, load capacity, maintenance and the need to adapt logistic concepts for the usage of EFVs.

The aim of the paper

The aim of the paper is to determine areas of effectiveness of transportation process of delivery confectionery products while using electric freight vehicle in the city.

Research system description

Most of the shipments in Ukraine are carried by vehicles with internal combustion engines and there are practically no examples of using EFVs. As an object, we chose transportation of confectionery products because it occupies a sufficiently large part of traffic in the city. There are wide ranges of different

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confectionary manufacturers in Ukraine on the one hand, and there is a huge demand for such products from consumers, on the other hand. For this reason, movement of confectionary good is motivating to research.

Particular attention during the organization of transportation requires confectionery. It is important to adhere to sanitary requirements and temperature regime. The group of these goods is perishable, so transportation should take minimal time. Permissible time of confectionery staying on the road depends on the timing of the sale of the products. An automobile carrying cargo transportation of confectionery products must be necessarily certified. Transportation is carried out in trucks with refrigerators, specialized vans, allowing to store the required temperature and humidity for a long time. Packing of products should keep their appearance. Products are packed in cardboard and plastic boxes, and fragile products are transported in corrugated boxes. However, it is unacceptable to assemble products at each other. For transportation in vans, special shelves should be provided. According to this special equipment for transportation, vehicles have such a high price.

At the first stage, we divided all confectionery manufacturers existing in Kharkiv into production sizes, including small, medium and large ones, Fig. 1. One of the largest manufacturers of confectionery products, which are sold within the city of Kharkiv, is the Kharkiv Biscuit Factory (Lozovsky str. 8).

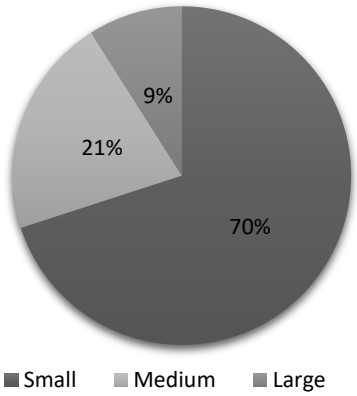

Fig. 1. Numbers of confectionery manufacturers in percentage

Consumers of finished products can also be distributed according to the size of consumption, namely: small retail chains, middle-store supermarkets and large retail chains. In this work, we chose middle supermarket chain "ATB". It is one of the biggest retail chains in Ukraine that is dynamically developing. This enterprise has about 56 supermarkets in Kharkiv, Fig. 2.

At the second stage, we chose two types of vehicles: electric driven and diesel driven to compare the effectiveness of its using. Capacity of the both vehicles are the same – 4,5 t., but each vehicle has its advantages and disadvantages.

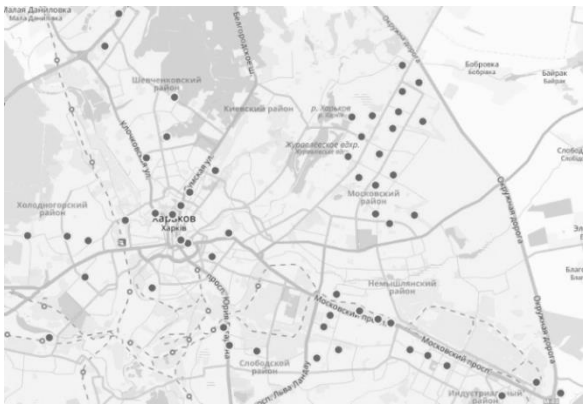

Fig. 2. Location of the "ATB" supermarkets in Kharkiv

For example, electric vehicle is eco-friendly because it runs on electrically powered engines. It is not produced emissions or other pollutants. However, EFV has limits by range (100 km) and recharging time. Diesel driven vehicle is more affordable, especially on the Ukrainian market. The general characteristics of vehicles is presented in Tab.1.

Table 1

Characteristics of vehicles

Parametrs	Fuso eCanter	Foton 1069
Fuel type	electric	diesel
Capacity, ton	4,5	4,5
Energy/fuel consumption/100km	82 kWh	15 L
Motor power, kW	115	101
Maximum speed, km/h	80	95
Price, thousand UAH	928	600

Modelling of delivery transportation process of confectionary products

The criterion of the effectiveness of transportation process is the total operating costs:

$$C \to \min. \qquad (1)$$

The mathematical model of the logistics chain has been developed. The mathematical model of an optimization:

$$C = \min\{\mathrm{C_E}; \mathrm{C}_D\}, \qquad (2)$$

where $\mathrm{C_E}$ – total operating costs while transporting cargo by electric vehicle, UAH per year; C_D – total operating costs while transporting cargo by diesel driven vehicle, UAH per year.

Total operating costs while transporting cargo by electric or diesel vehicle are calculated by the following formula:

$$C = C_s + C_r + C_f + C_t + C_g, \qquad (3)$$

where C_s – costs of salaries, UAH per year; C_r – maintenance costs of vehicle, UAH per year; C_f – fuel costs of vehicle, UAH per year; C_t – tire

costs, UAH per year; C_g – general expenses of operating activity, UAH per year

In order to conduct a comparative analysis of the efficiency of the using selected vehicles, it is necessary to form a technology for the operation of freight transport. During the development of the process of delivery confectionery products, the service "Ant Logistics" was used [13]. This platform allows building delivery routes, taking into account the following factors: type of car, load capacity, type of goods and their weight, journey time of delivery. Result of work in program is formation of three routes. The routes are shown in Fig. 3.

The main characteristics of developed routes are presented in Tab. 2.

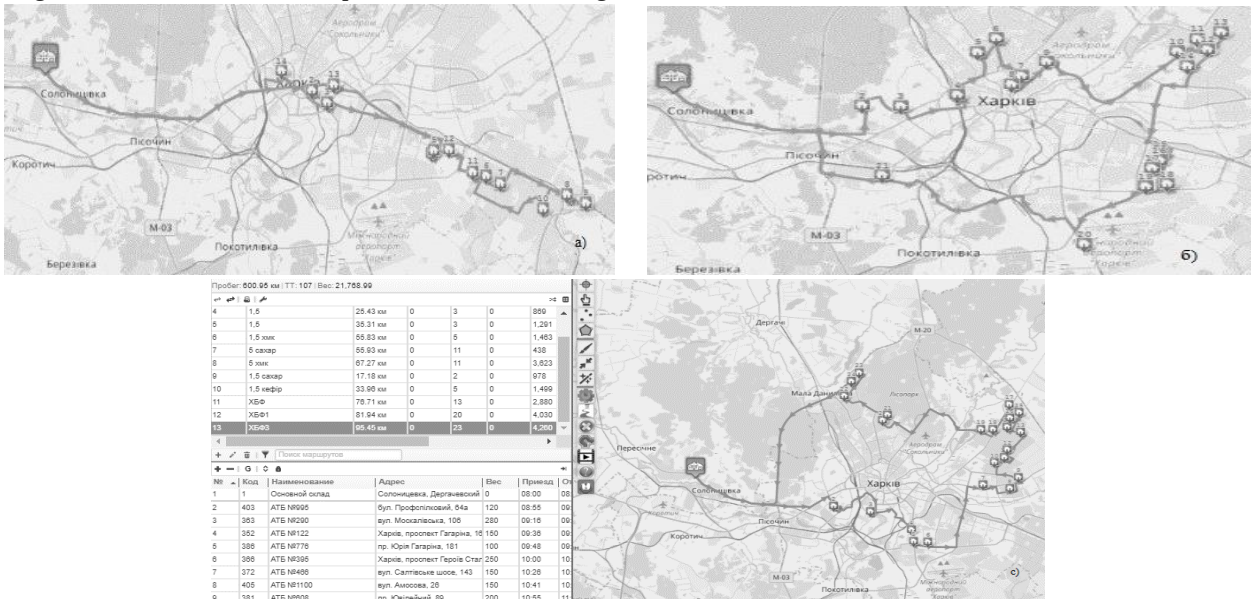

Fig. 3. Scheme of routes: a) route №1; b) route №2; c) route №3

Table 2

Characteristics of routes

Number of routes	Distance, km	Delivery time, h	Number of stops	Weight, kg
1	76,71	5,35	13	2 880
2	81,94	6,88	20	4 030
3	95,45	7,78	23	4 260

As the main limitation in our chosen electric vehicle is the mileage without recharging – 100 km, then our formed routes are suitable for both vehicles. Having analyzed the technology for the existing conditions, there are no differences. According to this information, we made a schedule of arrival in each store. Detailed information about points of delivery on first route is presented in Tab. 3.

Fig. 4 shows a schedule of the vehicle arrival to each supermarket.

Table 3

Schedule on route №1

№	Name of store	Address	Weight, kg	Distance, km	Arrival, h	Departure, h
1	Warehouse	Solonitsevka	0	0,00	8:00	8:30
2	ATB №406	Vernadsky str., 12	400	15,69	9:01	9:16
3	ATB №1056	Gagarina ave., 39 b	100	1,71	9:19	9:29
4	ATB №410	Tankopia str., 23	150	8,14	9:45	9:55
5	ATB №716	Kharkiv divisions str., 12 a	200	0,28	9:56	10:06
6	ATB №383	Aleksandrovsky ave., 85	200	4,04	10:14	10:24
7	ATB №738	Aleksandrovsky ave., 103/41	150	1,05	10:26	10:36
8	ATB №568	Moskovsky ave., 300	310	5,20	10:46	10:56
9	ATB №249	Velyka Kiltseva str., 3	200	1,48	10:59	11:09
10	ATB №1037	Roganska str., 100th	220	4,08	11:17	11:27
11	ATB №1007	Aleksandrovsky ave., 114	280	6,09	11:39	11:54
12	ATB №592	Rybalko str., 26	250	3,24	12:00	12:10
13	ATB №842	Zakhysnykiv Ukrainy sq., 7/8	220	7,99	12:26	12:36
14	ATB №457	Rizdviana str., 29 A	200	3,48	12:43	12:53
15	Warehouse	Solonitsevka	0	14,24	13:21	-

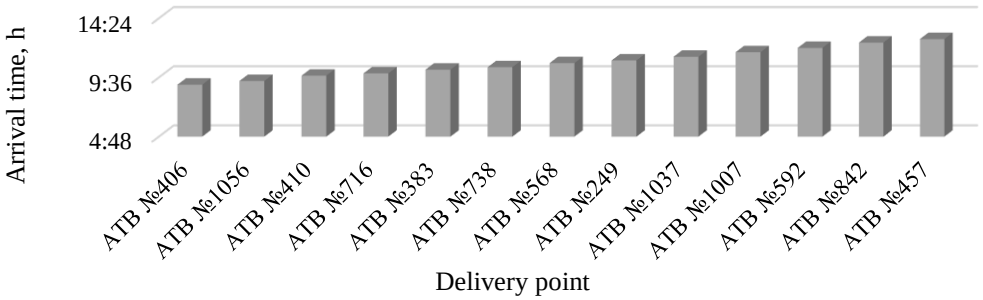

Fig. 4. Schedule of delivery goods on route №1

Analysis and assessment of transport activity is impossible without a set of indicators by which the volume and quality of its work is measured. Another important indicator is time, because transportation of confectionary products should occur in the shortest possible time. Delivery time consists of different stages, not all of them depends on transport operator. For instance, technological process of delivery can be split into different stages, Fig. 5. In this research we took into consideration time that vehicle spent for loading in the manufacture to time for unloading and time spent to return to manufacture (from last point).

Based on the received data from service Ant Logistics, the most important indicators, which allows to asses transportation process, were calculated, Tab. 4.

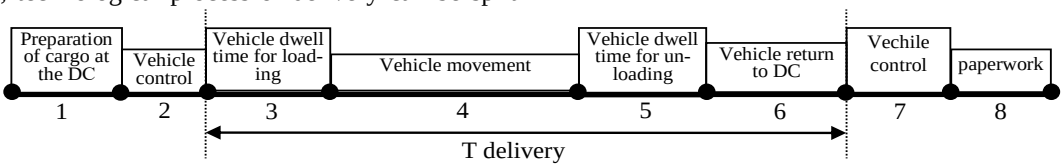

Fig. 5. Scheme of the transportation process delivery of confectionery in the city [14]

Table 4

Results of calculations of transport operation indicators on routes

№ of route	Distance, km	Mileage loading, km	Mileage from last point (no cargo), km	Time form depot to manufacture, h	Mileage use coefficient	Loading coefficient	Travel time, h	Loading/ unloading time, h	Delivery time, h
1	76,71	62,47	14,24	0,47	0,81	0,64	2,52	2,83	5,35
2	81,94	70,27	11,68	0,38	0,86	0,9	2,72	4,17	6,88
3	95,45	76,67	18,77	0,63	0,8	0,95	3,2	4,58	7,78

Having obtained full information about the formed routes, we can proceed to financial analysis of the effectiveness of transportation process using different vehicles, as this is the main indicator (3). The results are shown in Tab. 5. The difference between using diesel and electric vehicles is equal to 403679 UAH per year or to 41%. This is a quite significant value for transport operators, taking into account delivery only confectionary goods from one manufacture.

Table 5

Characteristics of operating costs on routes per year

Vehicle type	Costs of salaries, UAH	Maintenance costs of vehicle, UAH	Fuel costs of vehicle, UAH	Charge cost, (kWh per km), UAH	Tire costs, UAH	General expenses of operating activity, UAH	Total operating costs, UAH per year
Diesel	544500	60702,49	204554,2	-	12333,42	156197,1	978287,2
Electric	544500	501,35	-	8781,67	12333,42	8491,74	574608,1

Environmental assessment

The developed transport network plays a huge role in the development of the state, but this is accompanied by pronounced consequences of the negative impact of transport on the environment [16]. Among all types of transport, automobiles cause the greatest damage to the environment, polluting the air with toxic components. The highest level of air pollution is observed in urban area where people suffering the most [17, 18, 19].

From the point of view of the conducted financial analysis, there was a significant economy in finance by

41 % if using the electric truck. There is also indirect impact that can be assessed in improving the environmental indicators during use vehicles [20].

Environmental assessment we provide with software COPERT. This is a program, which was developed in Europe and used worldwide to calculate air pollution and greenhouse gas emissions from the road transport sector. Since we consider only the operation of vehicles, then our chosen electric vehicle is emission free, but with diesel vehicle, the situation is much more complicated. A diesel engine is a self-igniting engine in which fuel and air are mixed inside the engine. Numbers of harmful products are generated during combustion. The most significant harmful products are carbon monoxide, hydrocarbons, particulate matter and nitrogen oxides. In addition, it should be taken into account that the transport is one of the largest sector in producing global CO_2 emissions that leads to climate change [15]. Results of calculating emissions while transporting confectionery to "ATB" chain using methodology of COPERT is presented in Tab. 6.

Table 6

Diesel engine emissions per year (Foton 1069)

Emissions, kg	Urban Off Peak	Urban Peak	Highway	Total
CO_2	221,39	3527,9	516,86	4266,13
CO	0,2	5,3	0,5	6
NO_x	1,2	20	2,8	24
PM	0,1	1,6	0,3	1,9

Conclusion

The purpose of the paper was to determine the practicability of using the electric vehicle in city logistics, especially for transporting confectionary products in Kharkiv. We reviewed the process of delivery of the confectionery products of the Kharkiv Biscuit Factory through the network of supermarkets "ATB". Using a software product, we created routes and calculated the main indicators that allows estimating completed work on developed routes. In our paper, we consider technological process of delivery, in particular, time that vehicle spent for loading in the manufacture to time for returning to manufacture.

The main criterion for the effectiveness of transport on the routes was minimization of total operating cost. After conducting research, we concluded that the use of electric transport within the city for transportation at a given mileage can reduce total costs at least by 41 %. Also taking into account the indirect impact, we considered the effect from freight transport on the environment. Having analyzed the principle of operation of a diesel engine and what harmful substances it can produce, using the software product COPERT we calculated the main emissions from diesel vehicle (CO_2, CO, NO, PM) for the year.

Of course, comparing these two vehicles without a doubt under the given conditions, it is necessary to give preference to electric transport, which is gradually becoming popular not only in Europe, but also in Ukraine. Using of an electric vehicle, despite the fact that the cost of its buying is in several times higher than vehicles with internal combustion engines, in the process of operation, the electric shows quite good results. But in the further research it is appropriate to include in the model capital cost of vehicle and to apply economic analysis for evaluation results.

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ЕФЕКТИВНІСТЬ ПРОЦЕСУ ДОСТАВКИ ПІД ЧАС ВИКОРИСТАННЯ ЕЛЕКТРИЧНОГО ВАНТАЖНОГО ТРАНСПОРТУ

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Вплив міського вантажного транспорту на навколишнє середовище зростає із щільністю населення та бездіяльністю місцевої влади стосовно регулювання вантажного транспорту у місті. У дослідженнях Європейської Комісії у сфері логістики міський вантажний рух є більш забруднюючим, ніж перевезення на великі відстані, через середній термін експлуатації транспортних засобів та велику кількість коротких поїздок та зупинок. Вантажні перевезення – це приблизно чверть викидів CO_2 від транспортних операцій у містах. Одним із рішень для зменшення негативного впливу, що набуває популярності сьогодні, є використання вантажного електричного транспорту. На жаль, не так багато можна зустріти наукових робіт, присвячених оцінці ефективності вантажоперевезень по Україні, незважаючи на те, що в країні існують величезні екологічні проблеми. В даний час електромобілі є хорошою альтернативою для підвищення стійкості в міській логістиці.

Міський вантажний транспорт має важливе значення для транспортування вантажів, особливо кондитерських виробів, які користуються попитом і потребують особливої уваги під час перевезень. Ця стаття присвячена визначенню ефективності транспортного процесу під час доставки кондитерських виробів з використанням електричного вантажного автомобіля в межах міста. У якості критерію ефективності обрано експлуатаційні транспортні витрати.

Запропоновано два сценарії – використання електричного та дизельного типу вантажного транспорту з урахуванням основних особливостей транспортування кондитерських виробів. Було визначено технологію транспортного процесу доставки товарів. Оцінено основні показники роботи транспортних засобів на маршрутах, що були сформовані за допомогою он-лайн сервісу Ant Logistics. *Так, не було виявлено значних відмінностей між двома видами транспорту за технологією перевезення. Однак для проведення повного аналізу були визначені основні статті витрат. Існує тенденція до мінімізації експлуатаційних витрат під час користування електричним видом транспорту.*

Оскільки вплив вантажних перевезень на навколишнє середовище є одним із важливих факторів, було оцінено кількість викидів від дизельного двигуна за допомогою програмного продукту COPERT та зроблено висновки щодо переваг вибору виду транспорту для транспортування кондитерських виробів у Харкові.

Звичайно, порівнюючи ці два транспортні засоби в даних умовах, без сумніву слід віддати перевагу електричному транспорту, який поступово стає популярним не лише в Європі, а й в Україні. Використання електромобіля, незважаючи на те, що вартість його закупівлі в кілька разів вище, ніж транспортних засобів з двигунами внутрішнього згоряння, демонструє досить непогані результати. Але в подальших дослідженнях доцільно включити в модель капітальну вартість транспортних засобів і застосувати економічний аналіз для результатів оцінки.

Ключові слова: *міська логістика, електричний вантажний транспорт, маршрут, перевезення.*