Electronic scientific and practical journal

INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

#9 (2021)
October '21

WWW.SMART-SCM.ORG
ISSN 2708-3195
DOI.ORG/10.46783/SMART-SCM/2021-9

ISSN 2708-3195
9 772708 319005

Electronic scientific and practical collection
INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT

Electronic scientific and practical publication in economic sciences

ISSN 2708-3195
DOI: https://doi.org/10.46783/smart-scm/2021-9

Released 6 times a year

№ 9 (2021)
October 2021

Kyiv - 2021

Founder: Viold Limited Liability Company

The electronic scientific and practical journal is registered in international scientometric data bases, repositories and search engines. The main characteristic of the edition is the index of scientometric data bases, which reflects the importance and effectiveness of scientific publications using indicators such as quotation index, h-index and factor impact (the number of quotations within two years after publishing).

In 2020, the International Center for Periodicals (ISSN International Center, Paris) included the Electronic Scientific and Practical Edition "Intellectualization of Supply Chain Management" in the international register of periodicals and provided it with a numerical code of international identification: ISSN 2708-3195 (Online).

Recommended for dissemination on the Internet by the Academic Council of the Department of Logistics NAU (No. 7 of February 26, 2020). Released 6 times a year. Editions references are required. The view of the editorial board does not always coincide with that of the authors.

t.me/smart_scm
facebook.com/Smart.SCM.org
twitter.com/ScmSmart

DOI: https://doi.org/10.46783/smart-scm/2021-9
e-mail: support@smart-scm.org

тел.: (063) 593-30-41
https://smart-scm.org

Contents

INTRODUCTION 5

BUGAYKO D.O. PhD in Economics, Associate Professor, Vice - Director of International Cooperation and Education Institute, Instructor of ICAO Institute, Associate Professor of Logistics Dept. National Aviation University (Ukraine), **IERKOVSKA Y.M.** Lawyer (Ukraine)
INSTITUTIONAL MEASURES OF AIR TRANSPORT SAFETY STRATEGIC MANAGEMENT AT THE LEVEL OF STATE REGULATION 6 – 19

POZNIAK O.V. PhD (Economics), Associate Professor, Associate Professor of Logistics Department, National Aviation University (Ukraine), **KHMYLIEVSKA V.V.** PhD (Economics and Organization Management) Associate Professor (Organizational Management and Logistics department), F. Hoffmann La-Roche (Switzerland), **ISHIMWE M. J.** Master` degree student of Logistics Department, National Aviation University (Ukraine)
LOSSES IN PHARMACEUTICAL SUPPLY CHAINS: CHALLENGES IN EFFICIENT VACCINE DISTRIBUTION AND UTILIZATION 20 – 30

SAVCHENKO L.V. PhD of Technical Sciences, Associate Professor, Associate Professor of Logistics Department of National Aviation University (Ukraine), **SEMERIAHINA M.M.** Senior Lecturer of Logistics Department, National Aviation University (Ukraine), **SHEVCHENKO I.V.** PhD of Economic Sciences, Associate Professor of higher mathematics department of the National Aviation University (Ukraine)
MODELING DAILY DYNAMICS OF SPEED AND FUEL CONSUMPTION FOR URBAN DELIVERY MEANS 31 – 43

KOSTIUCHENKO L.V. PhD in Economics, Associate Professor, Associate Professor of logistics Department of National Aviation University (Ukraine), **MARCHUK V.Ye** Doctor of Engineering, Associate Professor, Professor of Logistics Department National Aviation University (Ukraine), **HARMASH O.M.,** PhD of Economics, Associate Professor, Associate Professor of Logistics Department of National Aviation University (Ukraine)
DEVELOPMENT OF RECYCLING INFRASTRUCTURE IN UKRAINE 44 – 52

SUMETS O.M. Doctor of Economics, Professor, Professor of The Integration Academy of Personnel Management (Ukraine)

THE EVENTUAL MODEL OF THE ALGORITHM FOR DESIGNING THE LOGISTICS SYSTEM OF A PRODUCTION ENTERPRISE 53 – 66

EVENTS AND SCIENTIFIC CONFERENCES
D.I. Solomon, P.I. Stetsiuk, M.Yu. Hryhorak – THE SCIENTIFIC CONFERENCE'S RESULTS: LOGISTIC VIEW "Mathematical modeling, optimization and information technology" 67 – 69

The electronic scientifically and practical journal 31-43
"INTELLECTUALIZATION OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT", v.9 (2021)
ISSN 2708-3195 https://smart-scm.org

UDC 338.27:656.1 DOI: https://doi.org/10.46783/smart-scm/2021-9-3
JEL Classification: R40, R41.
Received: 19 September 2021

Savchenko L.V. PhD of Technical Sciences, Associate Professor, Associate Professor of Logistics Department of National Aviation University (Ukraine)

ORCID – 0000-0003-3581-6942
Researcher ID – Q-5323-2018
Scopus author id: 57208225385

Semeriahina M.M. Senior Lecturer of Logistics Department, National Aviation University (Ukraine)

ORCID – 0000-0001-7490-6874
Researcher ID – S-7158-2018
Scopus author id: –

Shevchenko I.V. PhD of Economic Sciences, Associate Professor of higher mathematics department of the National Aviation University (Ukraine)

ORCID – 0000-0001-7910-0490
Researcher ID –
Scopus author id: –

MODELING DAILY DYNAMICS OF SPEED AND FUEL CONSUMPTION FOR URBAN DELIVERY MEANS

Lidiia Savchenko, Miroslava Semeriahina, Irina Shevchenko. "Modeling daily dynamics of speed and fuel consumption for urban delivery means". *Road transport is one of the most important elements of the functioning of a modern city. Maneuverability, mobility, speed of delivery of goods and other criteria have provided him with a special and leading place in urban logistics. However, along with the benefits of a developed transport network for society, its progress is accompanied by negative consequences for the environment and the population of the city. High rates of growth in the number of cars, especially in large cities, cause an increase in emissions of harmful products into the atmosphere, which, accordingly, negatively affects the health of the population. Consequently, the problem of environmental pollution in large cities from harmful emissions from vehicles requires an urgent solution.*

The increase in emissions of harmful substances is affected by an increase in the consumption of fuel materials due to a decrease in speed because of an increase in traffic density in the city. The frequency, duration, prevalence of congestion is increasing along with the urbanization of the population and the increase in the number of cars in cities. The dense development of the central historical districts of the city exacerbates the problem of unhindered passage of individual, public and freight vehicles. In addition, a decrease in the speed of city traffic affects the speed of delivery of goods, correspondence, etc., which negatively affects the speed of business processes, and ultimately worsens the level of logistics services for customers.

The purpose of this study is to analyze the current situation in terms of the dynamics of the average speed of the city's traffic flow by hours of the day and to obtain a mathematical model of the dependence of the speed of movement on the consumption of fuel materials for various environmentally friendly means of urban delivery (car, motorcycle, bicycle and pedestrian courier).

The research was carried out in two stages. At the first, the study of the dependence of the average speed of movement in the city on the time of day (for all means of city delivery) was carried out. At the second stage, the study of the dependence of the average consumption of fuel materials in the city (which, accordingly, is a function of the speed of movement) on the time of day for motorized urban delivery vehicles was done. In the course of the study, at each stage, an equation of the trend lines was obtained with a sufficient approximation accuracy.

In conclusion, the study proposes an algorithm for determining the average speed and average amount of fuel consumption when delivering small consignments in an urban environment using four urban logistics means - a car, a motorcycle, a bicycle, and a pedestrian courier (with the possibility of using public transport). The proposed algorithm can be applied in any delivery conditions in the city.

***Keywords**:* urban logistics, urban congestion, traffic speed, vehicle emissions, dynamics of traffic speed in a city, average fuel consumption, trend line equation.

Лідія Савченко, Мирослава Семерягіна, Ірина Шевченко. «Моделювання денної динаміки швидкості і витрат палива засобів міської доставки». *Автомобільний транспорт є одним з найважливіших елементів функціонування сучасного великого міста. Маневреність, мобільність, швидкість доставки вантажів та інші критерії забезпечили йому особливе та лідируюче місце у міській логістиці. Проте, разом з перевагами, що забезпечує суспільству розвинута транспортна мережа, її прогрес супроводжується негативними наслідками для навколишнього природного середовища та населення міста. Високі темпи росту кількості автомобілів, особливо у великих містах, зумовлюють зростання викидів шкідливих продуктів в атмосферу, що відповідно негативно впливає на стан здоров'я населення. Отже, проблема забруднення довкілля великих міст від шкідливих викидів автотранспорту вимагає невідкладного вирішення.*

На збільшення викидів шкідливих речовин впливає збільшення витрат паливних матеріалів за рахунок зниження швидкості через зростання щільності руху в місті. Частота, тривалість, розповсюдженість вуличних заторів зростають разом з урбанізацією населення та збільшенням кількості автомобілів у містах. Щільна забудова центральних історичних районів міста загострюють проблему безперешкодного проїзду індивідуального, громадського та вантажного автотранспорту. Крім того, зниження швидкості міського руху впливає на швидкість доставки вантажів, кореспонденції тощо, а це негативно позначається на швидкості бізнес-процесів, а у кінцевому рахунку погіршує рівень логістичного сервісу для клієнтів.

Метою даного дослідження є аналіз існуючої ситуації щодо динаміки середньої швидкості транспортного потоку міста за годинами доби та отримання математичної моделі залежності швидкості руху від витрат паливних матеріалів для різних екологічно дружніх засобів міської доставки (легковий автомобіль, мотоцикл, велосипед і пішохідний кур'єр).

Дослідження проводилося у два етапи. На першому проводилося вивчення залежності середньої швидкості руху містом від часу доби (для всіх засобів міської доставки). На другому - вивчення залежності середньої витрати паливних матеріалів у місті (які, відповідно, є функцією швидкості руху) від часу доби для моторизованих засобів міської доставки. Під час дослідження на кожному етапі отримано рівняння ліній тренду з достатньою точністю апроксимації.

На заключення у дослідженні запропоновано алгоритм визначення середньої швидкості та середньої кількості витрат паливних матеріалів під час доставки невеликих партій у міському середовищі за допомогою чотирьох засобів міської логістики – легкового автомобіля, мотоцикла, велосипеда та пішого кур'єра (з можливістю використання громадського транспорту). Запропонований алгоритм може бути застосовний у будь-яких умовах доставки містом.

Ключові слова: міська логістика, міські затори, швидкість руху, викиди автомобільного транспорту, динаміка швидкості руху в місті, середні витрати палива, рівняння лінії тренду.

Лидия Савченко, Мирослава Семерягина, Ирина Шевченко. «Моделирование дневной динамики скорости и расхода топлива средств городской доставки». *Автомобильный транспорт является одним из важнейших элементов функционирования современного города. Маневренность, мобильность, быстрота доставки грузов и другие критерии обеспечили ему особое и лидирующее место в городской логистике. Однако, вместе с преимуществами, обеспечивающими* *обществу развитая транспортная сеть, ее прогресс сопровождается негативными последствиями для окружающей природной среды и населения города. Высокие темпы роста количества автомобилей, особенно в крупных городах, обуславливают рост выбросов вредных продуктов в атмосферу, что соответственно отрицательно сказывается на состоянии здоровья населения. Следовательно, проблема загрязнения окружающей среды крупных городов от вредных выбросов автотранспорта требует безотлагательного решения.*

На увеличение выбросов вредных веществ влияет увеличение расхода топливных материалов за счет снижения скорости из-за роста плотности движения в городе. Частота, продолжительность, распространенность уличных пробок возрастают вместе с урбанизацией населения и увеличением количества автомобилей в городах. Плотная застройка центральных исторических районов города обостряет проблему беспрепятственного проезда индивидуального, общественного и грузового автотранспорта. Кроме того, снижение скорости городского движения влияет на скорость доставки грузов, корреспонденции и т.п., что негативно сказывается на скорости бизнес-процессов, а в конечном счете ухудшает уровень логистического сервиса для клиентов.

Целью данного исследования является анализ существующей ситуации по динамике средней скорости транспортного потока города по часам суток и получению математической модели зависимости скорости движения от расхода топливных материалов для разных экологически дружественных средств городской доставки (легковой автомобиль, мотоцикл, велосипед и пешеходный курьер).

Исследование проводилось в два этапа. На первом проводилось изучение зависимости средней скорости движения по городу от времени суток (для всех средств городской доставки). На втором – изучение зависимости среднего расхода топливных материалов в городе (что, соответственно, является функцией скорости движения) от времени суток для моторизованных средств городской доставки. В ходе исследования на каждом этапе получено уравнение линий тренда с достаточной точностью аппроксимации.

В заключение в исследовании предложен алгоритм определения средней скорости и среднего количества расхода топливных материалов при доставке небольших партий в городской среде с помощью четырех средств городской логистики – легкового автомобиля, мотоцикла, велосипеда и пешего курьера (с возможностью использования общественного транспорта). Предлагаемый алгоритм может быть применим в любых условиях доставки по городу.

Ключевые слова: городская логистика, городские пробки, скорость движения, выбросы автомобильного транспорта, динамика скорости движения в городе, средние расходы топлива, уравнение линии тренда.

Introduction. A decrease in speed due to growth in traffic density in the city leads to an increase in fuel consumption, and as a result, to an increase in emissions of harmful substances into the environment, which negatively affects the health of residents, green spaces, pollutes the facades of houses and infrastructure facilities. From an economic point of view, a decrease in the speed of city traffic is reflected in the speed of delivery of goods, correspondence, the speed of movement of workers, often at the expense of working time. A direct negative effect is increased fuel consumption on the commercial route. Road traffic emissions have dramatic local and global effects. Pollutants such as Nitrogen Oxides (NOx) and Particulate Matter (PM) have known detrimental impacts on human health, including respiratory and cardiovascular diseases [1], while Carbon Dioxide (CO2) emissions greatly contribute to global warming. Accurate trafficrelated emission estimations are thus crucial to assess their evolutions over several years, and to quantify the environmental impact of sustainable transportation policies such as lowemission zones and traffic regulation strategies [2].

Congestion is a major issue for cities and often a determining factor of connectivity within urban areas and intra-city interactions. It is a repercussion of the massive adoption of cars as the main transport mode and an externality related to the nature of cities as it represents the negative aspect of agglomeration, the major driving force of growth in cites [3].

According to the results of 2020, the capital of Ukraine was in seventh place in terms of congestion in the world [4].

Analysis of recent researches and publications. The report [5] analyses the factors influencing fuel consumption and CO2 emissions of passenger cars in real-world operating conditions. An extensive literature review has been performed, showing that the most important in-use factors affecting the difference between real-world and certification performance are the use of air conditioning devices, ambient temperature and environmental conditions, roof add-ons, driving style, tyre pressure and the increase of vehicle weight. For each factor a simulation scenario was designed to better investigate its effect. The authors emphasis that traffic conditions s (average speed, maximum speed, presence of traffic lights, free flow, etc.) affect the actual movement of the vehicle, average and max speed, accelerations, start and stop incidents, prolonged travel time, etc., that can have a very negative impact on fuel consumption.

The article [2] investigates the sensitivity of COPERT to the mean speed definition, and how COPERT emission functions can be adapted to cope with vehicle dynamics related to congestion. The research focuses on the urban area, because urban road traffic generates the highest emissions, caused by rapid speed variations and congestions [6, 7].

COPERT is the EU standard vehicle emissions calculator. It uses vehicle population, mileage, speed and other data such as ambient temperature and calculates emissions and energy consumption for a specific country or region. COPERT is internationally recognized — used by many European countries for reporting official emissions data. It calculates emissions at a national, regional or local scale, and for annual to daily estimates. COPERT's methodology is published and peer-reviewed by experts of the UNECE LRTAP Convention and includes all main pollutants: greenhouse gases, air pollutants and toxic species [8].

COPERT emissions are very sensitive to mean speed definition. Using a degraded speed definition leads to an underestimation ranging from -13% to -25% for fuel consumption during congested periods (from -17% to -36% respectively for NOx emissions). The mean speed definition has a considerable impact on COPERT fuel consumption and NOx emissions, even at the network scale [2].

Figure 1 shows the effect of vehicle speed on the rate of fuel consumption. It is obvious that as the velocity of the vehicle increases the air velocity around the vehicle will increase causing increases in the aerodynamic drag. The increase of the vehicle speed will create many separated flow regions on the curved surfaces of the vehicle body that will increase the overall drag, and consequently the rate of fuel consumption will be increased. It is noticed from Figure 1 that an increase in vehicle speed by 4% has increased the rate of fuel consumption by nearly 40%, which shows that both parameters are proportional [9]. An experimental work was conducted on four different vehicles, corresponding to different engine sizes (i.e. LADA 1.3cc, LADA 1.6cc, VW 1.3cc and Subaru 1.6cc).

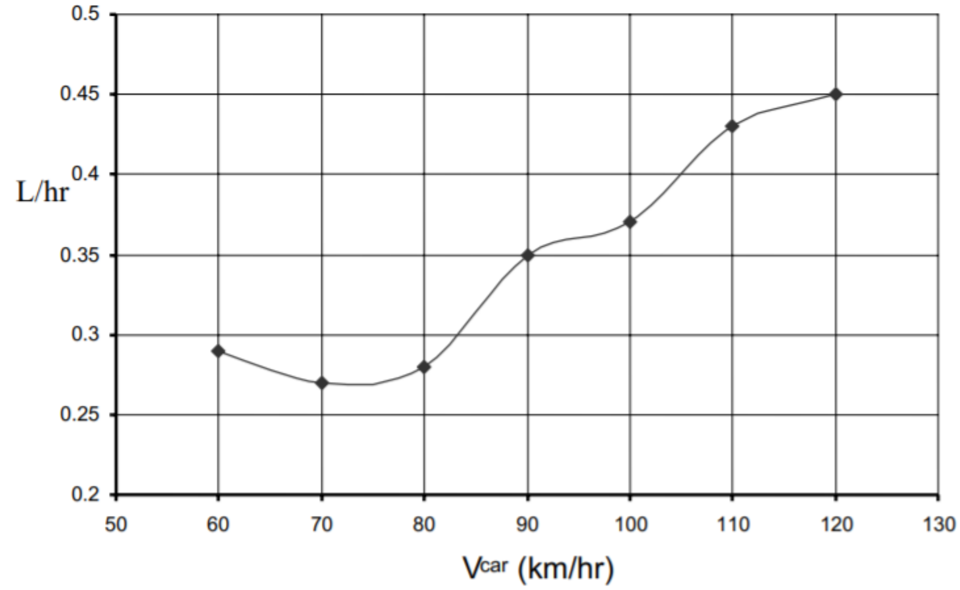

Figure 7. The effect of vehicle speed on the rate of fuel consumption [9]

The authors of [10] investigated that the effect of time-of-day on congestion duration depends on the day-of-the-week (Fig. 2).

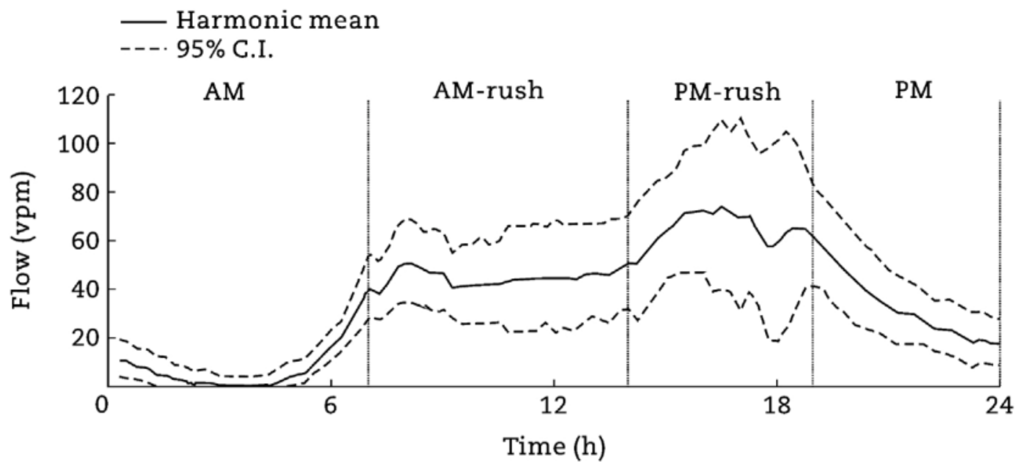

Figure 2. Average flow and variability by time-of-day [10]

The time-of-day measure was a categorical variable distinguishing between two time sectors: AM-rush (7 a.m.-2 p.m.) and PM-rush (2 p.m.-7 p.m.). The vast majority, more than 90%, of congestion events occur between 7 a.m. and 7 p.m. Within these 12 h, the AM-rush and PM-rush periods were distinguished based on a visual comparison of average flows throughout the day (Fig. 1). In a study [11] identified 3 p.m. as a natural break between midday and afternoon peak periods. In an analysis of recurring congestion, [12] identified AM- and PM-peak periods 5 a.m. - 8 a.m. and 3 p.m. - 7 p.m., respectively.

Authors [13] described the pattern of traffic flow in dependence with time of day (Fig. 3).

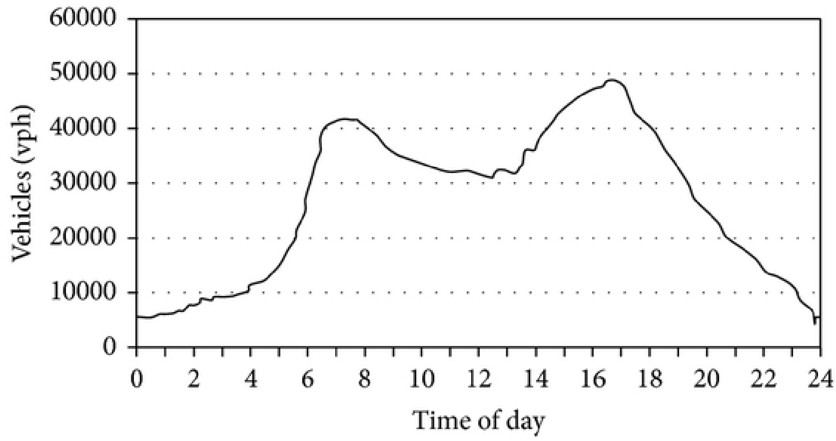

Figure 3. Typical traffic flow versus time of day [13]

A similar pattern can be found in the work [14], where typical dynamics of urban traffic speed is shown, with a significant decrease in speed in the morning and evening rush hours, the highest values at night, and obstructed movement during the day (Fig. 4).

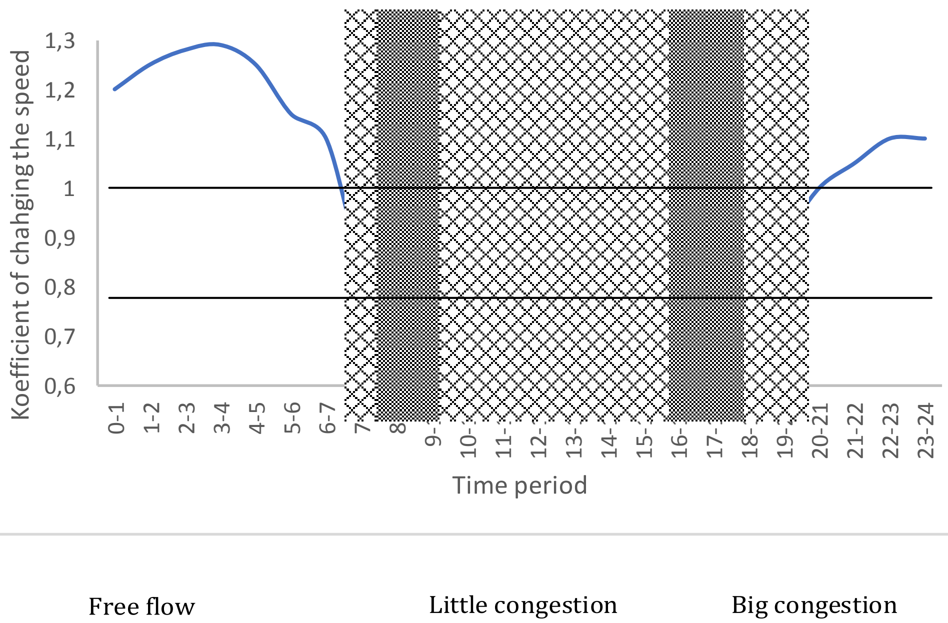

Figure 4. The coefficients of change in speed of movement depending on the time of day (completed based on [14])

The impact of congestion was measured with the help of the relevant TomTom indicators that provide very detailed information on the variation of speed during the day at road link level. Surprisingly, Seville has only one clear peak period, during the morning hours (Fig. 5). Working hours seem to play a role, most activities (distribution, work, school, shops) start between 6:00 am and 10:00 am, but return trips seem to cover a much wider period (from 2:00 pm to 11:00 pm) [15].

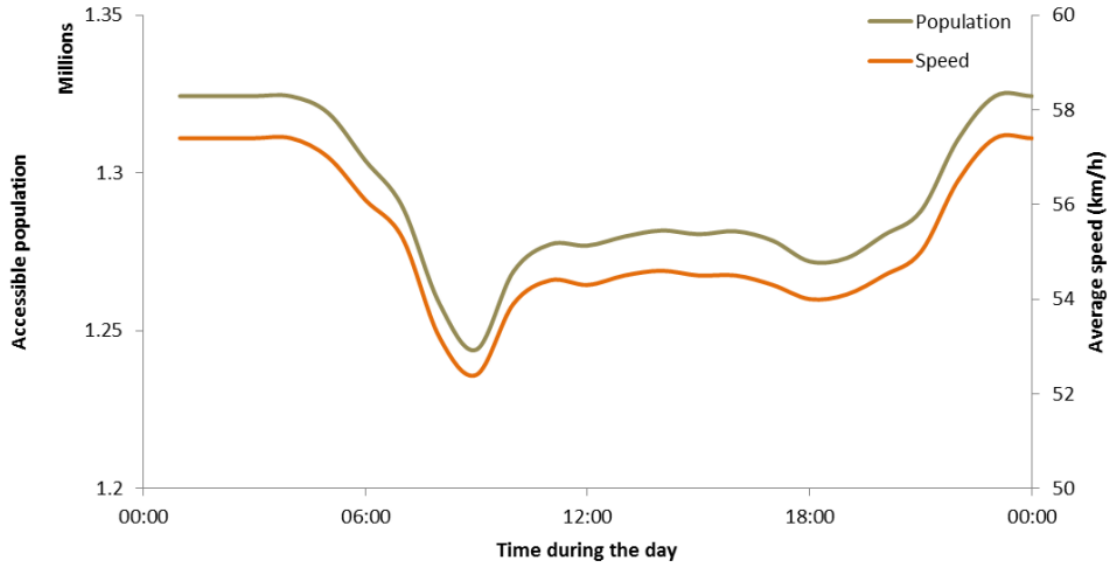

Figure 5. Hourly variation of absolute accessibility and speed during a day in Seville [15]

The urgency of the problem for Kyiv is caused by the fact that in Europe, Kyiv is the second most congested, behind Moscow and Istanbul (Fig. 6).

RANK BY FILTER	WORLD RANK ▼	CITY	DAYS WITH LOW TRAFFIC ▼	CONGESTION MONTH BY MONTH	CONGESTION LEVEL 2020 ▼
1	1	**Moscow region (oblast)** Russia	66 days		**54%**
2	2	**Mumbai** India	133 days		**53%**
3	3	**Bogota** Colombia	116 days		**53%**
4	4	**Manila** Philippines	128 days		**53%**
5	5	**Istanbul** Turkey	80 days		**51%**
6	6	**Bengaluru** India	147 days		**51%**
7	7	**Kyiv** Ukraine	48 days		**51%**
8	8	**New Delhi** India	64 days		**47%**
9	9	**Novosibirsk** Russia	15 days		**45%**
10	10	**Bangkok** Thailand	44 days		**44%**

Figure 6. The world's most congested cities in 2020 [4]

During 2020 alone, the congestion of Kyiv's roads increased by 2%. According to the authors of the rating, Kyivans and guests of the city lose about half an hour on the roads every day.

Kyiv roads are currently congested 3-4 times, according to the Kyiv City Administration. In 2020, 1.2 million cars were registered in Kyiv, of which 20% were trucks. At the same time, Kyiv is designed to use 300-400 thousand cars daily. Last year, the number of cars in the city increased by another 30% [16].

Thus, understanding the relationship "vehicle flow density - travel speed - fuel consumption" will effectively manage:

1) internal organizational logistics processes (for example, introducing off-peak, night-time delivery);

2) urban flows of vehicles and passengers, in order to reduce peak loads on road infrastructure (for example, by limiting the entry of cars to the busiest parts of the city, introducing high parking fees in certain areas, increasing the interval of public transport, etc.).

The purpose and objectives of the study. The purpose of this study is to analyze and obtain a mathematical model of the relationship between the speed of movement and fuel consumption for various means of urban delivery at different times of the day. A car, a motorcycle, a bicycle and a courier on foot (with the ability to use public transport) are considered as urban delivery means (UDM).

Basic material and results. The article discusses the dynamics of changes in speed and fuel consumption for such urban small cargo delivery vehicles:

– automobile;
– motorbike;
– bicycle;
– a courier on foot (with the possibility of using public transport).

The study will be divided into two parts - 1) to study the dependence of the average speed of movement in the city on the time of day (for all considered UDM); 2) to study the dependence of the average fuel consumption in the city on the time of day (for motorized UDM).

1. Average speed

To understand the conditions of the movements, data on the traffic flow by time of day is needed, namely, the speed and density of the vehicle movement [17].

Vehicle speed directly depends on the time of day and traffic congestion. At the same time, the speed of a motorcyclist depends on road congestion by only 33%, and of bicycles - by 20% [18]. Accordingly, the decrease in speed will be greatest for a car, and the least for a bicycle.

With regard to on-foot delivery, the distance between customers will affect the choice of courier movement. If the distance between clients is more than 1 km, the courier will use public transport, the speed of which is taken as 50% of a car speed (taking into account transfers, stops, waiting times, etc.).

In Kyiv, the movement of public transport occurs in the range of 7-23 hours, thus, we can observe the dynamics of speed during the day (Fig. 7).

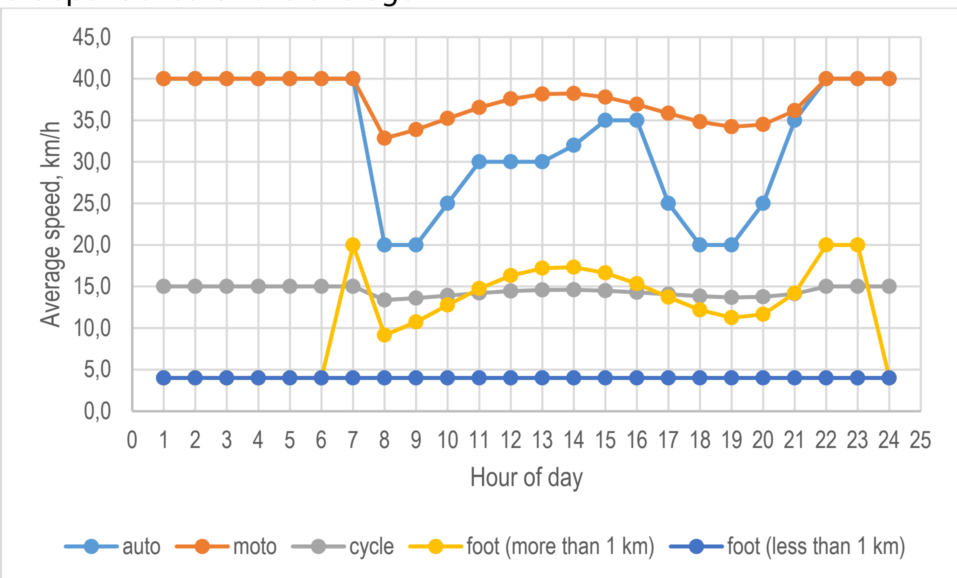

Figure 7. Dynamics of average speed at different urban delivery means

Given the real working conditions of the internet-store, the delivery of which is the object of work, the following work shifts were analyzed:

– 1st shift - 9.00-15.30;
– 2nd shift - 15.30-22.00.

Since all delivery means speed according to the methodology can be determined based on the speed of car deliver, the first step was to determine the function that most accurately describes the dynamics of the car and motorbike speed in Kyiv (Fig. 8).

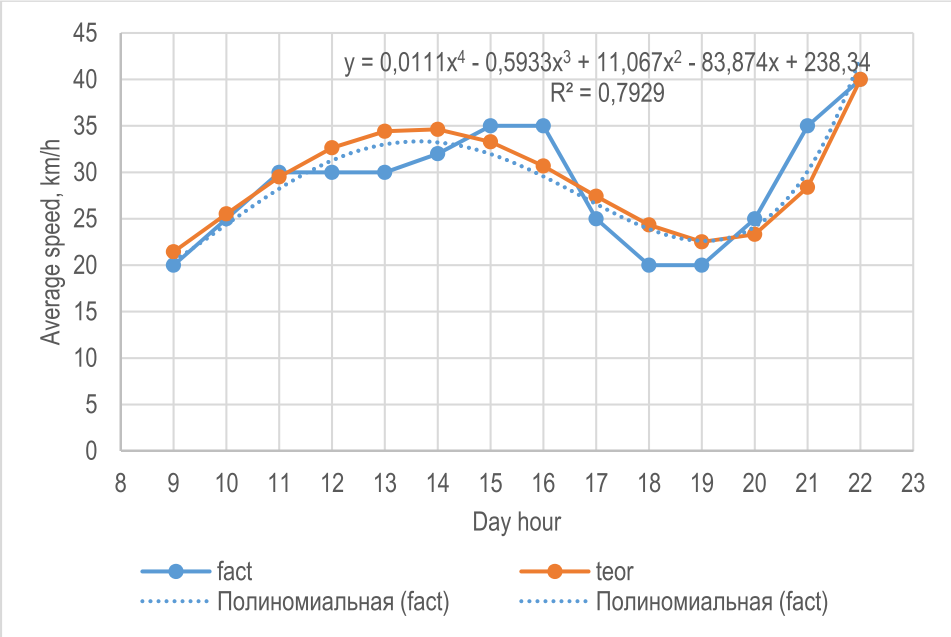

Figure 8. Dynamics of the average speed of delivery by car

The polynomial was chosen as such a function:

$$V(t) = 0,0111t^4 - 0,5933t^3 + 11,067t^2 - 83,874t + 238,34\,.$$

The accuracy is about 79%, which is an acceptable result.

Further, the dynamics of the speeds of other means were obtained (Fig. 9)..

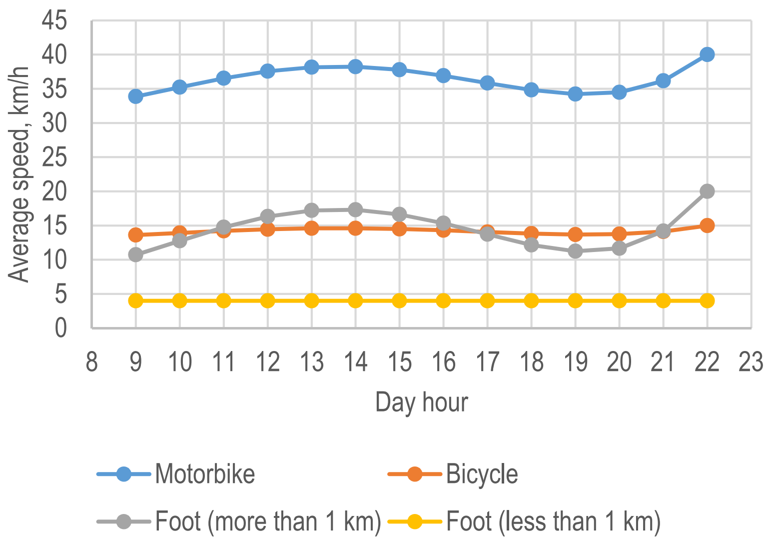

Figure 9. Dynamics of the average speed at different types of delivery (delivery hours 9.00-22.00)

Given the hourly change in traffic congestion, the calculation should be carried out in stages, in dynamics. However, to simplify the methodology, we took the average speeds for the shift, obtained as the arithmetic average of the speeds of each its hour. The final values of the average speeds of various means during shifts are shown in Table. 1.

Table 1. Average speeds for different types of delivery during a shift, km/h

Shift number	Automobile	Motorbike	Bicycle	Foot delivery (public transport)	Foot delivery (without public transport)
1	30,21	36,77	14,27	15,10	4,00
2	28,10	36,07	14,11	14,05	4,00

2. Average fuel consumption

Fuel costs are included in economic and environmental costs for only two of the four UDM involved in the analysis - car and motorcycle.

Fuel consumption for automobile delivery in the city is directly dependent on the speed of movement, which, in turn, is related to the density of urban traffic.

The cost of fuel on the route can be obtained based on the length of the route and fuel consumption per 100 km (considering the corresponding correction factor).

The fuel consumption on a route is influenced by the speed on the route. To calculate fuel consumption, it is proposed to use approximate trend lines that allow to describe the speed of movement depending on the time of day for each type of delivery vehicle V(t)i.

To obtain fuel consumption depending on the time of day, its dependence on the speed of movement for an average car and motorcycle in the city was studied (Fig. 10). We will restrict ourselves to the speed range of 10-50 km / h as the most probable, taking into account the limitations of the maximum speed in urban conditions by the traffic regulations.

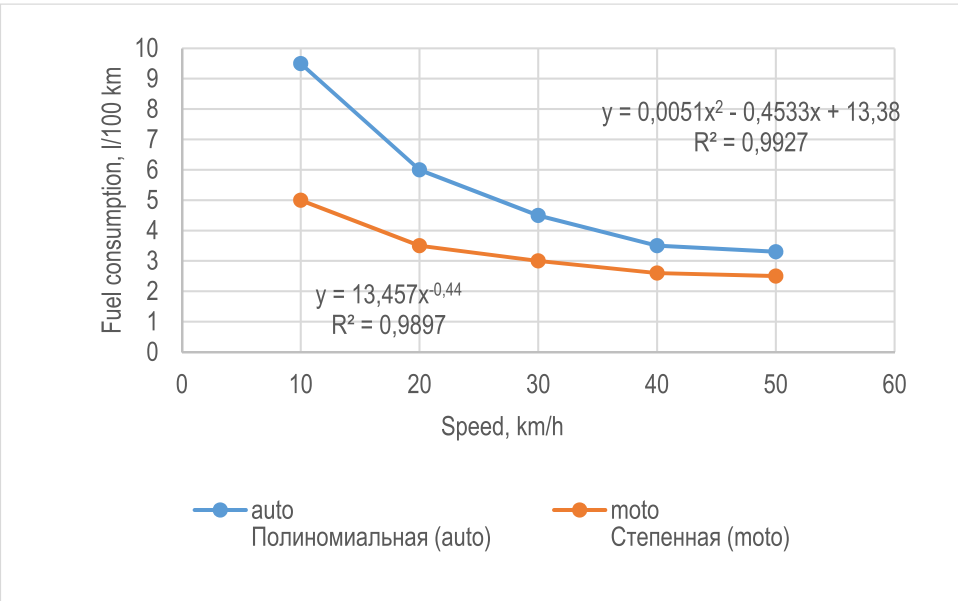

Figure 10. Dependence of fuel consumption on speed for an average car and a motorcycle with an engine capacity of 150-250 cm^3 (based on [13])

To simplify the calculations, the average values of fuel consumption per work shift can be obtained (Table 2). To do this, we find the arithmetic average of fuel consumption in each hour of the shift, having previously obtained these values using the trend line equations:

- for a car:

$$f_a(V) = 0,0051V^2 - 0,4533V + 13,38,$$

- for a motorcycle:

$$f_m(V) = 13,457V^{0,44}.$$

As we can see, MS Excel has selected a polynomial of the second order to describe the relationship for fuel consumption by a car and a power-law one - for fuel consumption by a motorcycle. Both models give excellent quality of approximation - R2 0.9927 and 0.9897, respectively.

Table 2 - Average fuel consumption for different types of delivery [l / 100 km]

Working Shift	Car	Motorbike	Bicycle	On foot / transit
1 (9 am to 3.5 pm)	4,63	2.78	-	-
2 (3.5 pm to 10 pm)	4,56	2.78	-	-

Conclusions. Thus, it is possible to propose an algorithm for determining the average speed and average fuel consumption when delivering small consignments in an urban environment using four means of urban logistics - a car, a motorcycle, a bicycle and an on-foot courier (with the possibility of using public transport) (Fig. 11).

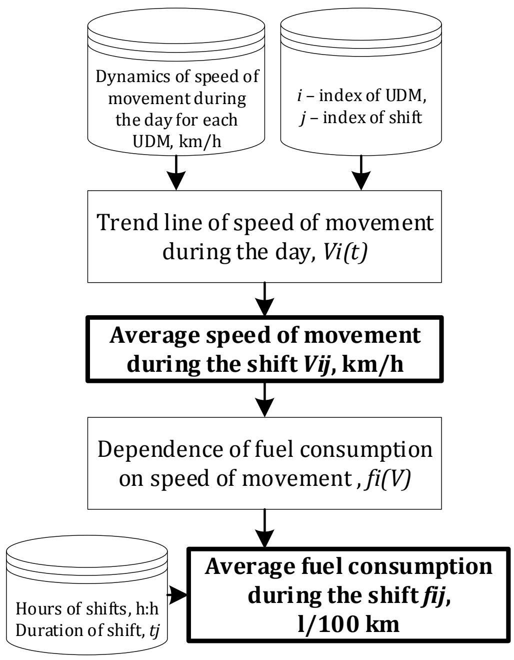

Figure 11. Algorithm for determining the average speed and average fuel consumption on urban delivery means

It should be noted that the numerical values obtained in the article are based on statistical data collected in a specific city (Kyiv) and cannot be automatically extended to all possible urban deliveries in the world. However, the proposed algorithm is applicable for any conditions of city delivery. One of its advantages is the absence of the need for special computer programs and the corresponding skills of a logistics manager. As an additional tool that facilitates calculations, a widespread program, usually present in any office, is offered - MS Excel.

As restrictions, it should be noted that the work does not take into account the number of customers on the route and the time spent at the moment of transfer of the shipment to a customer and for related operations. However, the authors believe that this simplification is acceptable for estimating the average speed of movement in the traffic flow, without taking into account stops and maneuvers at the place of delivery.

References

1. Shaughnessy, W.J., Venigalla, M.M., Trump, D. (2015). Health effects of ambient levels of respirable particulate matter (PM) on healthy, young-adult population. Atmos. Environ. URL: https://doi.org/10.1016/j.atmosenv.2015.10.039.

2. Lejri, D., Can, A., Schiper, N., Leclercq, L. (2018). Accounting for traffic speed dynamics when calculating COPERT and PHEM pollutant emissions at the urban scale. Transportation research part D: Transport and Environment, 63, pp. 588-603. URL: https://doi.org/10.1016/j.trd.2018.06.023.

3. Christodoulou, A. and Christidis, P. (2020). Measuring congestion in European cities, Publications Office of the European Union, Luxembourg. URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC118448.

4. Traffic Index 2020. Full ranking. URL: https://www.tomtom.com/en_gb/traffic-index/ranking.

5. Anagnostopoulos, K., Marotta, A., Pavlovic, J., Codrea, C. and Hodgson, I., editor(s), Zacharof, N., Fontaras, G., Ciuffo, B. and Tsiakmakis, S. (2016). Review of in use factors affecting the fuel consumption and CO2 emissions of passenger cars, Publications Office of the European Union, Luxembourg, URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC100150.

6. Ma, H., Xie, H.,Huang, D., Xiong, S. (2015). Effects of driving style on the fuel consumption of city buses under different road conditions and vehicle masses. Transp. Res. Part D Transp. Environ. 41, 205–216. URL: https://doi.org/10.1016/j.trd.2015.10.003.

7. Qu, L., Li, M., Chen, D., Lu, K., Jin, T., Xu, X. (2015). Multivariate analysis between driving condition and vehicle emission for light duty gasoline vehicles during rush hours. Atmos. Environ. 110, 103–110. URL: https://doi.org/10.1016/j.atmosenv.2015.03.038.

8. COPERT. URL: https://en.wikipedia.org/wiki/COPERT.

9. Al-Momani, M., Badran, O. (2007). Experimental investigation of factors affecting vehicle fuel consumption. URL: https://www.researchgate.net/publication/242474187_Experimental_investigation_of_factors_affecting_vehicle_fuel_consumption.

10. Laflamme, E.M., Ossenbruggen, P.J. (2017). Effect of time-of-day and day-of-the-week on congestion duration and breakdown: A case study at a bottleneck in Salem, NH, Journal of Traffic

and Transportation Engineering (English Edition), V. 4, Is. 1, pp. 31-40. URL: https://doi.org/10.1016/j.jtte.2016.08.004.

11. Hallenbeck, M.F., Ishimaru, J.M., Nee, J. (2003). Measurement of Recurring Versus Non-Recurring Congestion: Technical Report. WA-RD 568.1. Washington State Department of Transportation, Seattle. URL: https://www.wsdot.wa.gov/research/reports/fullreports/568.1.pdf.

12. Mazzenga, N.J., Demetsky, M.J. (2009). Investigation of Solutions to Recurring Congestion on Freeways. Virginia Transportation Research Council, Charlottesville. URL: https://trid.trb.org/view/887792.

13. Nasir, M. K., Noor, R. Md, Kalam, M. A., Masum, B. M. (2014). Reduction of Fuel Consumption and Exhaust Pollutant Using Intelligent Transport Systems. The Scientific World Journal, Article ID 836375. URL: https://doi.org/10.1155/2014/836375.

14. Ehmke J.F., Mattfeld, D. (2012). Vehicle Routing for Attended Home Delivery in City Logistics. Social and Behavioral Sciences 39: 622–632. URL: https://doi.org/10.1016/j.sbspro.2012.03.135.

15. Christodoulou, A., Christidis, P. (2020). Measuring congestion in European cities, Publications Office of the European Union, Luxembourg, URL: https://publications.jrc.ec.europa.eu/repository/handle/JRC118448.

16. Баркар, D. (2021). 9 днів у заторах: дороги Києва перевантажені у кілька разів. URL: https://www.radiosvoboda.org/a/zatory-kyiv-transport-optymizatsiya/31282821.html.

17. Rhodes S. S., Berndt M., Bingham P., Bryan J., Cherrett T. J., Plumeau P., Weisbrod R. (2012). NCFRP REPORT 14. National Academies of Sciences, Engineering, and Medicine. Guidebook for Understanding Urban Goods Movement. Washington, DC: The National Academies Press. URL: https://doi.org/10.17226/14648.

18. Comi, A., Savchenko, L. (2021). Last-mile delivering: Analysis of environment-friendly transport. Sustainable Cities and Society, Volume 74, 103213. URL: https://doi.org/10.1016/j.scs.2021.103213.