UDC 629.33/36+625.7

S.V. Myronenko, PhD, Assoc.Prof.,
A.S. Wenger,
S.V. Atmazhov
Automobile and Road College of Odessa National Polytechnic University, 6 Tiraspolska Str., 65045 Odessa, Ukraine;
e-mail: mirserg@ukr.net

CAPACITY ANALYSIS OF THE STREET AND ROAD NETWORK OF MODERN REGIONAL CENTER

С.В. Мироненко, А.С. Венгер, С.В. Атмажов. **Аналіз пропускної здатності вулично-дорожньої мережі сучасного регіонального центра.** Збільшення інтенсивності руху транспорту, зміна структури і швидкісних режимів транспортних потоків пред'являють усе жорсткіші вимоги до засобів керування і організації дорожнього руху для забезпечення необхідного рівня ефективності і безпеки останнього. Для вирішення цієї проблеми необхідно побудувати оптимальну за довжиною, щільністю й транспортно-експлуатаційними показниками вулично-дорожню мережу. ***Мета:*** Метою дослідження є оцінка завантаженості й аналіз пропускної здатності вулично-дорожньої мережі сучасного регіонального центра. ***Матеріали і методи:*** Всі дослідження й розрахунки в роботі авторами проведено на прикладі вулично-дорожньої мережі Приморського району м. Одеси (Україна). Для оцінки пропускної здатності було обрано декілька вулиць – транзитних артерій історичного центра міста. Саме по них відбувається рух до основного пасажиро- і транспортно-утворюючого вузла – залізничного вокзалу. Для оцінки пропускної здатності розглянутої вулично-дорожньої мережі було використано методи натурних спостережень, тому що їх засновано на проведенні безпосередніх вимірювань характеристик дорожнього руху у різних місцях вулично-дорожньої мережі. ***Результати:*** Проведене дослідження дало об'єктивну картину найважливіших кореспонденцій. Проведено оцінку ступеня завантаження розглянутої вулично-дорожньої мережі, для чого обчислено розрахункову пропускну здатність багатосмугової проїзної частини. Аналіз отриманих даних показав, що стан потоку транспорту у досліджуваному районі щільно насичений. Вироблено рекомендації для вдосконалення організації дорожнього руху сучасного регіонального центру.

Ключові слова: пропускна здатність, вулично-дорожня мережа, транспортні засоби, інтенсивність руху, організація дорожнього руху.

S.V. Myronenko, A.S. Wenger, S.V. Atmazhov. **Capacity analysis of the street and road network of modern regional center.** Increasing the intensity of transport traffic, changing in restructuring and high-speed modes of transport flows more stringent requirements for controls and traffic management impose to ensure the necessary level of efficiency and safety of the transport traffic. To resolve this problem, it is necessary to build road network optimal in length, density and on transport performance indicators. ***Aim:*** The aim of the study is to evaluate the workload and analysis of capacity of the road network of modern regional center. ***Materials and Methods:*** All studies and calculations in paper, the authors conducted on the example of the road network of the Primorsky district of Odessa (Ukraine). Few streets that are transit arteries of the historic center were chosen to assess the road network capacity. On these streets the movement to the main passenger and transport creating unit – Railway Station is happening. To assess the capacity of the considered road network the methods of field observations were used, because they are based on direct measurements of traffic characteristics in different parts of the road network. ***Results:*** The study gave an objective picture of important correspondences. An assessment of degree of loading the considered road network was made; for that the capacity of multilane roadway was calculated. Analysis of the data showed that the state of traffic in the study area is densely saturated. It was made the recommendation for improvement of traffic of modern regional center.

Keywords: capacity, street and road network, transportation, traffic, traffic organization.

Introduction. Road Transportation firmly entrenched in modern life, providing a large the volume of transportations in all spheres of human activity. Motor transportation became an integral link in the transport process on almost all modes of transport.

Increasing the intensity of transport traffic, changing in restructuring and high-speed modes of transport flows more stringent requirements for controls and traffic management impose to ensure the necessary level of efficiency and safety of the transport traffic. To resolve this problem, it is necessary to build road network optimal in length, density and on transport performance indicators.

However, the experience of most developed countries shows that the development of such network can not be in isolation from the constant targeted traffic planning and road equipment with special technical devices for organizing and operating of traffic management [1…3].

Significant growth in vehicle fleet and in traffic leads to increased traffic. In terms of cities with historical buildings it causes the traffic problems. Particularly acute this problem arises in the nodal

DOI 10.15276/opu.3.50.2016.06

ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

points of road network where traffic delays increases. The resulting queues and congestion cause a decrease in speed connections, unnecessarily excessive fuel consumption and increased wear of components and assemblies vehicles [1].

The most important criterion that characterizes the functioning of routes is their capacity. Under the capacity of the road authors understand the maximum number of units of rolling stock that can go on the road, driving with the calculated speed in one direction by time period.

Capacity is divided into three types: actual, estimated and project. Determining the actual capacity is only possible on active roads. These data have a particularly great practical importance, since it allows a realistic assessment of capacity while ensuring a certain level of speed and safety [4].

In the works of contemporary experts in the field of transport is described different ways of regulating of traffic on roads and complex highways, as well as methods of designing of economic transport systems with high bandwidth. The methods of calculating capacity are given in the works of N. Bellomo *et al.* [5], M. Garavello, and B. Piccoli [6], B.S. Kerner [7] and others.

The aim of the study is to evaluate the workload and analysis of capacity of the road network of modern regional center.

Materials and Methods. Depending on the purpose of the study of traffic there are different methods to determine its characteristics: documentary, nature, modeling [1, 2, 7].

All studies and calculations in this paper the authors conducted on the example of street and road network of the Primorsky district of Odessa (Ukraine). To assess capacity the next street were chosen: Katerynyns'ka, Rishelievs'ka, Pushkins'ka, Kanatna, Greches'ka, Velyka Arnauts'ka. These streets were chosen due to the fact that they are transit arteries of the historic center. On these streets the movement to the main passenger and transport creating unit – Railway Station is happening. The historic city center has a rectangular building scheme, which helped to organize one-way traffic by streets Rishelievs'ka, Pushkins'ka, and Velyka Arnauts'ka. Scheme of road network with these streets is shown in Fig. 1.

To assess the capacity of the considered street and road network the methods of field observations were used, because they are based on direct measurements of characteristics of traffic in different parts of network. In the absence of automatic counters and lack of access to video surveillance in these streets full scale methods only can achieve goal.

Results and Discussion. To get the most accurate data the information on speed and traffic density, composition of traffic flow were collected through direct observation for the period 18.-24.04.2016 at different times of the day. The data about the composition of traffic flow and road traffic received on different days of the week and at different times of day, was optimized and presented in graphs (Fig. 2...7).

In natural studies also studied the characteristics of the road conditions, such as number of traffic lanes, speed, type of road surface (Table 1).

Observation posts, which are marked with Roman numerals in Fig. 8, were located in specific points (focus of attraction of traffic) of the considered street and road network.

Fig. 1. Scheme of street and road network of the Primorsky district of Odessa

Table 1

Characteristics of road conditions

Street	Number of traffic lanes, ps	Speed of movement, km/h	Surface type
Katerynyns'ka	4	41	asphalt
Rishelievs'ka	4	32	asphalt
Pushkins'ka	3	30	paving stone
Kanatna	3	28	asphalt
Greches'ka	2	26	asphalt
Velyka Arnauts'ka	3	35	asphalt

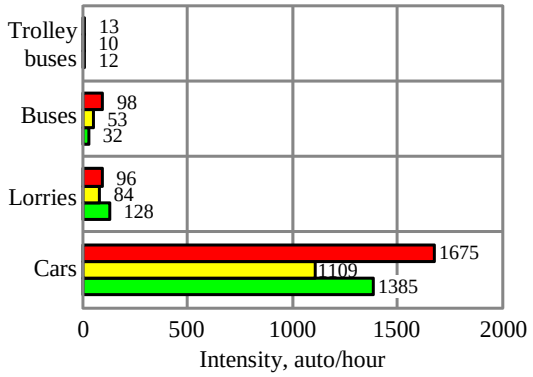

Fig. 2. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Katerynyns'ka Street (intensity: – 17:00…18:00; – 12:00…13:00; – 8:00…9:00)

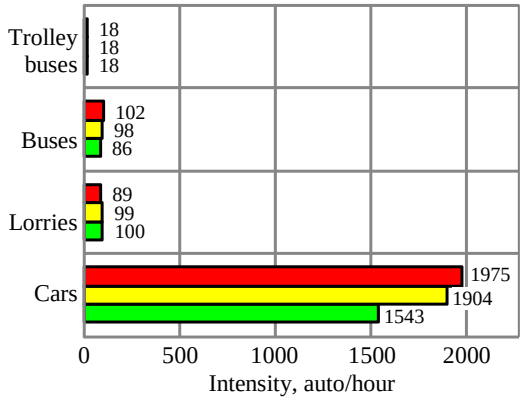

Fig. 3. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Rishelievs'ka Street (intensity: – 17:00…18:00; – 12:00…13:00; – 8:00…9:00)

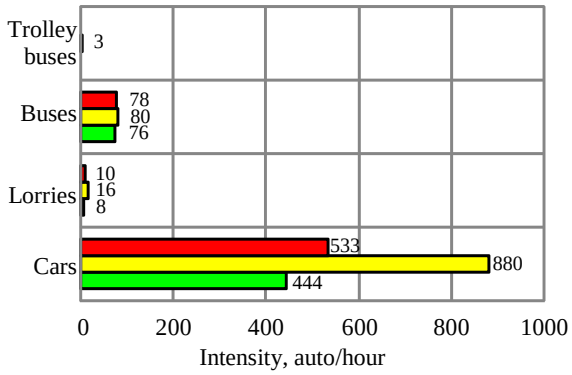

Fig. 4. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Pushkins'ka Street (intensity: – 17:00…18:00; – 12:00…13:00; – 8:00…9:00)

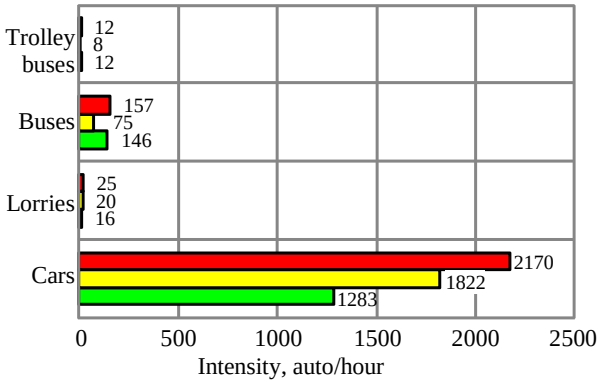

Fig. 5. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Kanatna Street (intensity: – 17:00…18:00; – 12:00…12:00; – 8:00…9:00)

ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

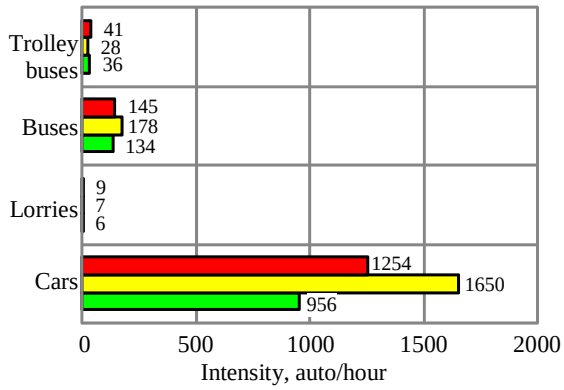

Fig. 6. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Greches'ka Street (intensity: – 17:00…18:00; – 12:00…13:00; – 8:00…9:00)

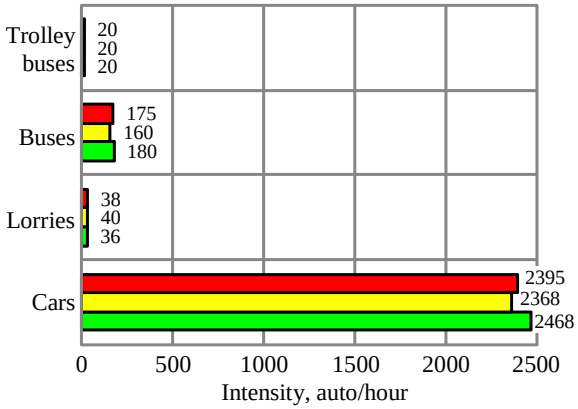

Fig. 7. The graph of dependence of the intensity of traffic from the composition of traffic flow and time of day for the Velyka Arnauts'ka Street (intensity: – 17:00…18:00; – 12:00…13:00; – 8:00…9:00)

The study gave an objective picture of important correspondence.

Fig. 9 presents a matrix of correspondence, which shows basic information obtained as a result of research: the numerator – the intensity of traffic flow (*N*, auto/hour); the denominator – the connection speed (v_c, km/h) for the main lines.

Fig. 8. Scheme of control posts

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I						895 32							
II	1882 35												
III		1497 33						1700 42					
IV			1409 36		2184 28								
V				1009 33		1033 30							424 38
VI	827 37				592 40							979 41	
VII		2188 31											
VIII							42 40		2272 31				
IX										2364 30			
X											1863 26		340 52
XI							2704 32			267 28		1583 29	
XII						842 36					443 27		
XIII					544 33					340 53			

Fig. 9. Matrix of correspondences

The next stage of research was to evaluate the degree of loading of the considered street and road network. It is necessary to calculate the estimated capacity of multilane road P_M, which is a product of the actual capacity and correction factors. For this purpose, we use the formula given in [8]:

$$P_M = P_n n \varepsilon \alpha,$$

where P_n – the estimated capacity of one lane (1070…1340 auto/hour);

n – number of lanes;

ε – coefficient of distribution of vehicles across the width of the roadway (0.95…0.85);

α – factor taking into account the impact of crossing the road (0.4…0.6).

The calculation results are presented in Table 2.

The level of road downloading estimated by load factor z [8] which is the ratio of the traffic intensity to estimated traffic capacity of the considered areas of the street or road. So in this case, for each direction of motion the load level is defined as

$$z = \frac{N}{P_M}.$$

The calculation results are presented in Table 3.

Table 2

Estimated capacity of the streets

Street	Estimated capacity, hour^{-1}
Katerynyns'ka	2440
Rishelievs'ka	2440
Pushkins'ka	1830
Kanatna	1830
Greches'ka	1220
Velyka Arnauts'ka	1830

Table 3

Calculation of traffic downloading of the road network

Street	Intensity, auto/hour	Estimated capacity, hour^{-1}	The level of downloading, z	State of flow
Katerynyns'ka	979	2440	0.40	Partly connected
Rishelievs'ka	2704	2440	1.11	Dense saturated
Pushkins'ka	2364	1830	1.29	Dense saturated
Kanatna	2184	1830	1.19	Dense saturated
Greches'ka	1863	1220	1.53	Dense saturated
Velyka Arnauts'ka	1882	1830	1.03	Dense saturated

From the analysis of the table data it follows that the condition of traffic on referred streets densely saturated. This means that the flow is moving with stops, there are traffic jams. Therefore, this issue needs careful study as is the basis for the study and forecasting of capacity of the street and road network.

Conclusions. We have analyzed the capacity of the road network of Primorsky district of Odessa.

Selective study found that the road network of Primorsky district of Odessa needs a complete renovation. To improve traffic organization is first necessary to build a model of the transport network.

Special attention also require the following issues: preparation of characteristics of the provisions and appointments of the road network as systems of transport and pedestrian links between elements of planning structure of the city; analysis of the planning scheme of city; diagramming of cargo flows; determine the duration of loading operations at points; calculation of the intensity, of the level of loading and density of traffic flow; determining the capacity of roads, interval of motion, time and speed of communication on routes to improve traffic organization of public passenger transport; determining the long-term city plan of passenger transport system through modelling; assembly the topology scheme of the city; determining the capacity of transport areas; calculation of passenger traffic in the network.

For rapid traffic organization is necessary to solve the problem with sites for the parking. The study found that traffic signs of prohibiting stopping and parking do not affect the drivers therefore need to take more stringent measures, such as the use of tow trucks and the system of fines. This will increase the capacity of street and road network by 20...30% without large investments.

Література

1. Paterson, S.E. Road traffic: Safety, modeling and impacts / S.E. Paterson, L.K. Allan. — New York: Nova Science Publishers, 2009. — 560 p.
2. Road engineering for development / ed. by R. Robinson, B. Thagesen. — 2nd Ed. — London; New York: Spon Press, 2004. — 514 p.

ISSN 2076-2429 (print)
ISSN 2223-3814 (online)

3. Vasconcellos, E.A. Urban transport, environment, and equity: The case for developing countries / E.A. Vasconcellos. — London: Earthscan Publications, 2001. — 344 p.
4. Roess, R.P. The highway capacity manual: A conceptual and research history. Volume 1, Uninterrupted flow / R.P. Roess, E.S. Prassas. — Berlin: Springer, 2014. — Vol. 1. — 470 p.
5. Bellomo, N. On the mathematical theory of vehicular traffic flow I: Fluid dynamic and kinetic modelling / N. Bellomo, M. Delitala, V. Coscia // Mathematical Models and Methods in Applied Sciences. — 2002. — Vol. 12, Issue 12. — PP. 1801 — 1843.
6. Garavello, M. Traffic flow on networks / M. Garavello, B. Piccoli. — Springfield: American Institute of Mathematical Sciences, 2006. — 243 p.
7. Kerner, B.S. Introduction to modern traffic flow theory and control: The long road to three-phase traffic theory / B.S. Kerner. — Berlin: Springer, 2009. — 265 p.
8. Клинковштейн, Г.И. Организация дорожного движения / Г.И. Клинковштейн, М.Б. Афанасьев. — 4-е изд., перераб. и доп. — М.: Транспорт, 1997. — 231 с.

References

1. Paterson, S.E., & Allan, L.K. (2009). *Road Traffic: Safety, Modeling and Impacts*. New York: Nova Science Publishers.
2. Robinson, R., & Thagesen, B. (2004). *Road Engineering for Development* (2nd Ed.). London; New York: Spon Press.
3. Vasconcellos, E.A. (2001). *Urban Transport, Environment, and Equity: The Case for Developing Countries*. London: Earthscan Publications.
4. Roess, R.P., & Prassas, E.S. (2014). *The Highway Capacity Manual: A Conceptual and Research History. Vol. 1, Uninterrupted Flow*. Berlin: Springer.
5. Bellomo, N., Delitala, M., & Coscia, V. (2002). On the mathematical theory of vehicular traffic flow I: Fluid dynamic and kinetic modeling. *Mathematical Models and Methods in Applied Sciences*, 12(12), 1801—1843. DOI:10.1142/S0218202502002343
6. Garavello, M., & Piccoli, B. (2006). *Traffic Flow on Networks*. Springfield: American Institute of Mathematical Sciences.
7. Kerner, B.S. (2009). *Introduction to Modern Traffic Flow Theory and Control: The Long Road to Three-Phase Traffic Theory*. Berlin: Springer.
8. Klinkovshtein, G.I., & Afanas'yev, M.B. (1997). *Road Traffic Organization* (4th Ed.). Moscow: Transport.

Received October 5, 2016
Accepted November 23, 2016