Determining the acceptable walking distance when servicing cars by parking facilities

Cite as: AIP Conference Proceedings **2439**, 020013 (2021); https://doi.org/10.1063/5.0068456
Published Online: 12 October 2021

Oleksandr Severyn, Olha Kholodova, Olha Shulika, et al.

Determining the Acceptable Walking Distance when Servicing Cars by Parking Facilities

Oleksandr Severyn [1], Olha Kholodova[2, a)], Olha Shulika[1], Nataliia Semchenko[2], Yevgeniya Novikova [3]

[1]*Department of Transport Technologies, Kharkiv National Automobile Highway University, 61002, 25 Yaroslav Mudry Str., Kharkiv, Ukraine*
[2]*Department of Traffic Management and Road Safety, Kharkiv National Automobile Highway University, 61002, 25 Yaroslav Mudry Str., Kharkiv, Ukraine*
[3]*Department of Foreign Languages, Kharkiv National Automobile Highway University, 61002, 25 Yaroslav Mudry Str., Kharkiv, Ukraine*

[a)] *Corresponding author: olgakholodova2807@ukr.net*

Abstract. A definition of the "attractive" average walking distance in the downtown using the "gravity centre" criterion to determine the location of the vehicle parking facility has been suggested. The application of the criterion is based on the demanded quantity of parking spaces near the trip destination. The calculations have shown the possibility of reducing the walking distance when covering the vast majority of users, which will contribute to a positive decision by the majority of potential users to use the suggested parking facility, and will also provide a certain guarantee of improving the economic performance of the parking systems.

INTRODUCTION

A significant increase in the number of chaotic car parking directly near trip destinations (retail facilities, headquarters of banks, companies, etc.) is a consequence of increasing the population's business activity and the desire for "convenience" when using parking facilities (PF). This leads to traffic congestion in cities and towns, especially in their downtowns (DT), a decrease in the average speed of vehicles, and an increase in the time of their movement or being in traffic jams.

When determining a rational parking space, the transport gravity centre is taken into account. It depends on the location of the objects visited by users, the number of people desired to use the PF, the walking distance and the time of users' approach to the trip destinations, as well as the parking rate, where the most significant is the total time of approaching that depends on the walking distance (service radius), taking into account the location of permitted pedestrian crossings and the density of pedestrian traffic. That is, the PF rational location depends on the value of the set maximum acceptable (attractive) average value of the walking distance in the DT, the provision of which will contribute to the potential consumer decision of using the suggested PF and will provide an economic basis for such facilities locating.

In the sources of scientific and technical information, scientists have paid enough attention to the issue of rational PF locating for passenger cars in the DT [1-16]. The analysis of the materials on setting the average value of the walking distance, carried out by the authors, showed that one of the obstacles to solving this problem is the requirements of regulatory documents [11] intended for forming the infrastructure of settlements, including the street and road network of the downtowns. Besides, the cited regulatory documents do not contain the information on the method of justifying the indicated distance figures.

Transport, Ecology - Sustainable Development EKO Varna 2021
AIP Conf. Proc. 2439, 020013-1–020013-6; https://doi.org/10.1063/5.0068456
Published by AIP Publishing. 978-0-7354-4140-8/$30.00

The data on solving the problem of parking space locating and the method of setting the value of the walking distance is given in works [5-10, 12-16]. Thus, when locating car parking facilities in the DT J. Oppenlander recommends providing the minimum possible average value of pedestrian traffic, taking into account the size of the settlement, its topography, the type of parking facility, the purpose of travel, the parking rate and its belonging [5]. That is, with an increase in the population, the walking distance value can vary within wide limits. It is recommended to set its value for a particular city using field studies.

G. Levinson [5] found that the walking distance value in the DT varies depending on the city size, associated with the location of public transport stops and car parking facilities concerning large shops and institutions. The author has divided pedestrian traffic into two main categories: between public transport stops or car parking facilities and places of employment; between retail outlets and facilities in shopping areas. This feature of pedestrian traffic should be taken into account when forming traffic downtown.

D. Cleveland [5] recommends setting a boundary for the study not only the source of the parking problem (downtown, industrial vehicle fleet, etc.) but also the surrounding area, covering a "reasonable distance" within 90… 450 m from the parking lot. The method of setting the value of such a distance is not explained.

The authors of study [6] provide information that the distance walked by the user from the PF to the trip destination is smaller in size than the distance to the public transport stop. Therefore, the owners of parking facilities convince users to stop using public transport, because of the comfort of using PF. The authors argue that locating the PF should be performed so that the interval between PFs in terms of distance will be as close as possible to the nearest stops on the public transport routes.

V. Golubnichyi [7] determined that the capacity of the object of a permanent parking N_n depends on the values of the average service radius R. Based on the data presented in this work, we have found out that this dependence is exponential and has the following form

$$R = 30,61e^{0,444N_n} \tag{1}$$

The research carried out by the author is not aimed at solving the problem of PF locating to reduce the amount of chaotic parking on the street-road network of the downtown.

Yu. Ignatiev [8] suggests differentiating the parking space parameters of different types in city zones, taking into account various factors and some regularities between the main parking indicators and the suggested dependence is recommended to use only in preliminary calculations when designing and building a parking system.

O. Kholodova offers to determine the maximum service radius of PF users depending on the size of the N_n parking capacity and the k_c coefficient of changing the maximum radius, that can be adjusted taking into account the most "convenient" walking distance suggested in [9,10]

$$R = k_c \cdot \sqrt{N_n} \tag{2}$$

The recommendation is based on attractiveness for the user – the higher the parking rate is, the less time he/she should spend on walking from the parking space to the destination. The coordinates of the designated space serve as a reference point for the calculated service radius for PF users. This procedure for setting the location for the allocated micro-district does not guarantee that the radius will be within the attractiveness range because the weight (an advantage in number) of users is not taken into account, otherwise, it is necessary to set a different number of them for downtown. This means that the value of the acceptable radius is limited by the micro-district size. If the radius is smaller, then not all the users' trip destinations will be in the service area of the PF belonging to it. Besides, the suggested method of dividing into zones does not take into account the available number and density of locating the users' trip destinations in the downtown area. All these considerations will result in unjustified changing the service radius value and, as a consequence, certain losses of PF attractiveness.

In [12] it is noted that parking spaces should not be beyond the "convenient" walking distance of 300 m. No justification for this value is provided.

Works [13, 14] present the results of studying the value of walking distance depending on four different purposes of the trip: daily shopping, weekly shopping, work and social activities. Six distance categories were identified ranging from 50 m to 700 m, and the synergy between the maximum distance acceptable to drivers and their driving characteristics and trip characteristics was shown on the basis of polynomial regression analysis. Among the above-

noted characteristics associated with the trip, in particular, “frequency of using the car” and “visit duration” are the most influential.

In the study [15] the conditions influencing the value of the walking distance of the PF users are presented: the purpose of the trip, the individual trip, the time available for the trip and the surroundings where the trip takes place. The authors suggest expanding the list of conditions, which should be taken into account: types of users, frequency of travel, user’s familiarity with the object, perception of safety, presence or absence of obstacles or conflicts, cost and availability of alternatives. According to the authors, taking into account additional factors will allow one to turn down empirical rules and create adequate manuals for parking design.

Thus, the conducted review of literature has shown the following:

1. Regulatory documents ordering the formation of the settlement infrastructure only recommend the value of the walking distance for users of permanent parking facilities when designing new residential areas without specifying the method of PF locating and the distance value of the walking distance.

2. The issue of walking in cities and towns shows the desire of the majority of car users to cover short distances, reflecting the desire to save time spent on travel, avoid the inconvenience of such travels, find a parking place faster and pay less for it.

3. The average walking distance, among other factors, is determined as the most powerful and attractive reason for choosing a particular PF by a potential user. It should be smaller than the average approach distance to a public transport stop.

4. Nowadays, there is no universally accepted approach to the choice of PF location with attractive walking distance for users to their destinations. Therefore, there are some doubts about the prospects of economic feasibility and maintenance of such facilities.

EXPOSITION

The work aims to determine the “attractive” average walking distance in the downtown using the “gravity centre” criterion for determining the location of the vehicle PF, which will contribute to a positive decision of potential users to use the suggested PF.

To determine the maximum acceptable average walking distance in downtowns as the most powerful reason that influences a potential decision of the user to use the suggested PF, a hypothesis was put forward about the possibility of using the “gravity centre” criterion to set a location and then optimize it.

The coordinates of a certain PF are taken as the starting point for fixing the radius value of the walking distance. Such a solution is aimed at using micro districts of cities or towns without PFs or optimizing the location of existing ones.

The use of such a method for determining the PF location is possible only by taking into account the peculiarities of current infrastructure and operating conditions of vehicles inherent in the downtown of a given city.

For each transport micro-district coordinates, based on field studies, are determined, recorded on the map and the possible number of parking spaces near the objects, that are the purpose of the user’s trip, is set. The obtained values serve as the required capacity of transport micro districts and are used to calculate the PF location with a given number of parking spaces. The availability of services for PF users can be assessed by the criteria of the number of users and the quality of service, assessed by experts.

Today the “gravity centre” criterion is a well-known way of solving various problems of setting coordinates and their optimization in practice: locating the intermediate warehouses for storing goods, distribution centres, ambulance stations, parking spaces for fire fighting vehicles, etc. [17, 18]. A similar method can be applied when optimizing the PF location for each selected micro-district of the downtown. It is suggested to determine the PF location as the gravity centre coordinates of the required number of parking spaces, which satisfies the needs of most users and helps to minimize the walking distance

$$X = \sum_{i=1}^{n} m_i \cdot x_i / \sum_{i=1}^{n} m_i \tag{3}$$

$$Y = \sum_{i=1}^{n} m_i \cdot y_i / \sum_{i=1}^{n} m_i \tag{4}$$

where X, Y are gravity centre coordinates; n is the number of users' objects; m_i is the number of required parking spaces for the i-th user's object; x_i, y_i are coordinates of the i-th object.

The use of the criterion is possible only under the condition of a developed street network in the city, for example, for a radial-circular shape of street location.

The PF location along certain coordinates is not always possible due to various obstacles [19]. This leads to increasing the costs of PF construction and maintenance and, as a result, to the search for a final solution among alternative locations to reduce these costs. That is, there are a lot of Pareto optimal alternatives for PF locating.

The search for the optimal location can be carried out using the function of the sum of the $R_{x,y}$ distances from the PF coordinates to the coordinates of the objects – the purpose of users' destinations, taking into account additional weight factors on parking spaces [17]

$$R_{x,y} = \sum_{i=1}^{n} p_i \sqrt{(X - x_i)^2 + (Y - y_i)^2} \tag{5}$$

where p_i, x_i and y_i are the weighting factors regarding demand and the coordinates of the i-th object – the purpose of the potential user's destination respectively; X, Y are PF coordinates, set according to the gravity centres.

In models for specifying the PF location according to function (5) the smallest one is taken among the options for PF locating. The introduction of additional weighting factors (for example, specifying the object attractiveness according to service quality, the importance and urgency of the user's trip, etc.) is accompanied by the complexity of their determination by a certain accuracy.

Materials from experimental studies given in [9] were taken to test the hypothesis about the possibility of using the above-mentioned criterion to set a PF rational location. They are the following: a map with a DT division into micro districts; object location – the purpose of users' destinations and the amount of demand for parking places near them; the PF gave coordinates for each micro-district.

For example, calculating the PF coordinates and determining the radius of the walking distance according to the suggested method we's performed for micro districts 4, 9 and 10. The analysis was carried out by comparing the values of the coordinates indicated in the above-mentioned work. The FP layout is shown in Fig. 1.

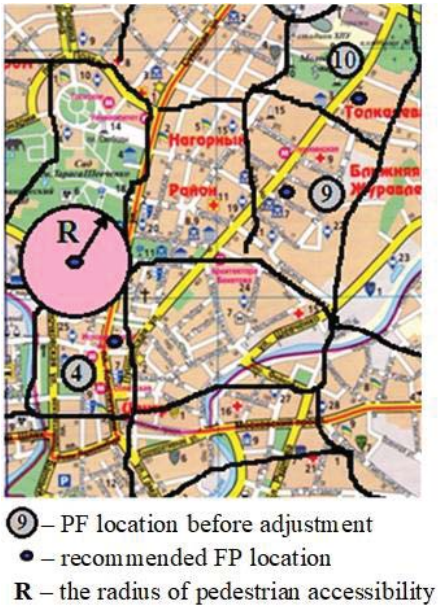

FIGURE 1. PF layout

Comparing the values of the walking distance, determined in the work and using the suggested method, showed that it is possible to reduce the radius by 204 m for PF 4, by 183 m for PF 9 and by 42 m for PF 10 when covering more than 90 % of the object users.

To determine the values of additional weighting factors as to the demand for parking spaces, a survey of different age potential respondents that use vehicles for their trips to the corresponding objects was carried out. Taking into account a defined demand allows us to adapt the vehicle parking mode to the most likely users.

Well-known international rating companies that conduct marketing research (COMCON-2, GFK, Nielsen, Gallup Institute, etc.) use the concepts of random and non-random sampling. When calculating the weighting factors non-random sampling was used, in which the adequacy of the obtained results was high.

The statistical size of the marketing research sample was determined with an error value of less than 3%, which corresponds to the desired accuracy and a set level of reliability. The survey was carried out in conditions when the respondent had enough thoughts on the problem posed in the field of road transportation.

Calculating the sum of users travel distance from two alternatives PFs to the necessary ones according to their purposes showed that the $R_{x,y}$ values of the suggested locations are lower for object 4 by 8.4%, object 9 by 32.6% and object 10 by 14.7% relatively.

At the same time, it should be noted that the sample among the object users is not completely certain, because the procedure for obtaining information from residents of a given settlement and those who arrived from others is too complicated to cover all participants in these trips.

If a sufficiently large number of users cannot be covered in the area defined by the service radius of a given PF for a micro-district, it is necessary to reconsider the approach to the method of DT microzoning and to make the above-given calculations once more.

CONCLUSION

The results of the study make it possible to set the PF location (parking spaces) in the downtown using the “gravity centre” criterion and, if necessary, subsequent optimization of the coordinates according to the criterion of “the sum of the user travel distance”.

The PF location determined in this way will be closer to the travel destination of most users, which will significantly reduce the walking distance for them when servicing cars. The calculations of the sum of users travel distance for the examples given in the study showed that the walking distance decreases by 20% on average. Therefore, the suggested methodology can be recommended to infrastructure specialists for implementing when developing car parking systems.

Reducing the walking distance gives a certain guarantee of attracting the majority of users to park their cars at the micro-district facility and, as a consequence, improving the economic performance of its functioning.

REFERENCES

1. The manual for locating parking spaces, garages and service stations of cars in cities and othersettlements (to the SNiP 11-60-75 *) (Stroyizdat, Moscow, 1984).
2. SNiP 2.07.01-89* Urban planning. Planning and development of urban and rural settlements (Stroyizdat, Moscow, 1989).
3. T. F. Panchenko et al, Urban planning. Designer’s Handbook (DNB 360.92) (Ukrarkhbudinform, Kiev, 2001).
4. T. Badayants, Transport facilities. Parking lots and garages for cars: DBN B.2.3-15:2007 (Minbud Ukrainy, Kiev, 2007).
5. V. U. Renkin, P. Klafi, S. Halbert, Dzh. K. Oppenlender et al, Automobile transportation and traffic management: Handbook (Transport, Moscow, 1981), p. 592
6. P. Christiansen, O. Engebretsen, N. Fearnley and J. U. Hanssen, Transportation research part a-policy and practice **95,** 198-206 (2017).
7. V. A. Holubnychyi, J. Mistobuduvannia ta terytorialne planuvannia **12,** 31-41 (2012).
8. Yu. V. Ignatev, J. Vestnik YuUrGU Seriya: Stroitelstvo i arhitektura **17,** 68-72 (2012).
9. O. O. Kholodova, “Forming parking systems in downtowns of cities and towns”, Ph.D. thesis, KhNADU, 2013.

10. O. O. Kholodova, J. Avtomobil' i elektronika. Sovremennye tekhnologii **8,** 90-94 (2015), available at http://www.khadi.kharkov.ua/nauka/naukovo-doslidna-chastina/naukovi-vidannja/avtomobil-elektronika-suchasni-tekhnologiji/arkhiv-nomeriv.html.
11. O. O. Kholodova, O. O. Severyn and O. O. Shulika, Tekhnichnyi servis ahropromyslovoho, lisovoho ta transportnoho kompleksiv **12,** 281-287 (2018).
12. V. V. Sheshtokas, City and transport (Stroyizdat, Moscow, 1984), p. 176.
13. P. van der Waerden, H. Timmermans and M. de Bruin-Verhoeven, J. Transport and Land **10,** 1, 1-11, (2017), available at: http://jtlu.org.
14. M. B. W. Kobus, E. Gutiérrez-i-Puigarnau, P. Rietveld and J. N. Van Ommeren, J. Reg. Sci. and Urban Econom **43,** 2, 395-403 (2013).
15. M. S. Smith and T. A. Butcher, National association parking **33**, 8, 29-32 (1994), available at https://www.gsweventcenter.com/GSW_RTC_References/2008_05_Smith-Butcher.pdf.
16. P. F. Gorbachev and I. A. Dmitriev, Fundamentals of the theory of transport systems (HNADU, Kharkiv, 2002), p. 202.
17. A. V. Katrenko and T. I. Antoniak, J. Visnyk Natsionalnoho universytetu "Lvivska politekhnika" Informatsiini systemy ta merezhi **715**, 150-162 (2011).
18. R. Z. Farahani and M. Hekmatfar (eds.) Facility Location: Concepts, Models, Algorithms and Case Studies Contributions to Management Science, (Physica-Verlag, Heidelberg, 2009) p. 549.
19. S. Henley, The Architecture of Parking (Thames and Hudson, USA, 2007), p. 256.