UDC: 656.84 DOI: http://dx.doi.org/10.7708/ijtte2023.13(1).04

IMPLEMENTATION OF MOBILE PARCEL LOCKERS IN DELIVERY SYSTEMS – ANALYSIS BY THE AHP APPROACH

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Received 19 January 2023; accepted 28 February 2023

Abstract: Delivery companies are trying to improve their business and thus respond to the increased number of requests due to the expansion of e-commerce. In addition, one of the basic parameters of the quality of the delivery service - availability, is increasingly difficult to maintain at an appropriate level due to the circumstances arising from the modern way of life and business. Users find it more and more difficult to use the services of shipments because their business and private obligations coincide with the working hours of delivery companies. One of the most modern solutions in the field of improving accessibility in this area is the application of mobile parcel lockers. The results of the analysis of their implementation by the AHP approach are presented in this paper.

Keywords: shipment transfer, service availability, mobile parcel lockers, AHP method.

1. Introduction

Modern delivery systems have a developed network and technical equipment, as well as a specialized workforce. However, when the system is loaded with many user requests, organizing and realization of business activities are very challenging. The technological process of transfer of shipments consists of several steps, with last-mile delivery being one of the most technologically and financially demanding (Mizutani & Uranishi, 2003; Ralević *et al.,* 2016; Muharemović *et al.,* 2021). Companies dealing with delivery strive to optimize their business processes, both in terms of costs and in terms of the quality of the service provided. Numerous studies dealing with improving the functioning of the transfer of shipments system can be found in the literature (Ćirović *et al.,* 2014; Dobrodolac *et al.,* 2015, 2016; Šarac *et al.,* 2016; Lazarević *et al.,* 2020; Mostarac *et al.,* 2021). To optimize delivery, companies resort to different solutions. One of the proposed solutions is to offer a service with improved time availability (Lazarević *et al.,* 2020). Also, in practice, the introduction of self-service machines that are available to users 24 hours a day, 7 days a week is increasingly present (Vrba *et al.,* 2022). In addition to delivery, in this way users can also be offered the dropping of consignments for transfer. This is mainly about parcel lockers, which are slowly becoming part of the infrastructure of postal networks around the world. In the era of e-commerce expansion, they enable practical shopping because by addressing the parcel locker, users can be sure that the package will be waiting for them at the chosen

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location. A step further is the implementation and use of mobile parcel lockers, the main advantage of which is mobility in a certain territory (Schwerdfeger & Boysen, 2020). The actuality of the application of classic and mobile parcel lockers (MPL) in the world is also indicated by the fact that there are numerous studies that are primarily related to the optimization of their use and its impact on the environment (Iwan *et al.,* 2016; Wang *et al.,* 2020; Ghaderi *et al.,* 2022; Peppel & Spinler, 2022; Schwerdfeger & Boysen, 2022).

In this paper, a methodology for the analysis of the implementation of mobile parcel lockers in the transfer of shipments system is proposed and the results of its application in the framework of the domestic market are presented.

2. Methodology

For an adequate analysis of the implementation of mobile parcel machines in the shipment transmission system, an appropriate methodology is proposed, which is based on the active participation of experts. First, a matrix of influential factors is formed, which are placed in one of the groups, depending on the characteristics. Accordingly, four groups of factors are formed: social, economic, ecological, and technical. In this way, it is possible to look at the subject of analysis from several aspects. To gain insight into the mutual relationship, that is, the relative importance between groups and between defined factors, the principles of the AHP method are applied, which are based on the comparison of pairs, according to Saaty's comparison scale (Saaty, 1977). Experts give their opinions (assessments) on the relationship between all defined groups and on the relationship and interaction of factors within each group. Based on the scores, the relative importance of each group and factor is determined (both by group and globally at the level of the entire matrix). The proposed model is presented in several steps in Figure 1 (Dobrodolac *et al.,* 2016).

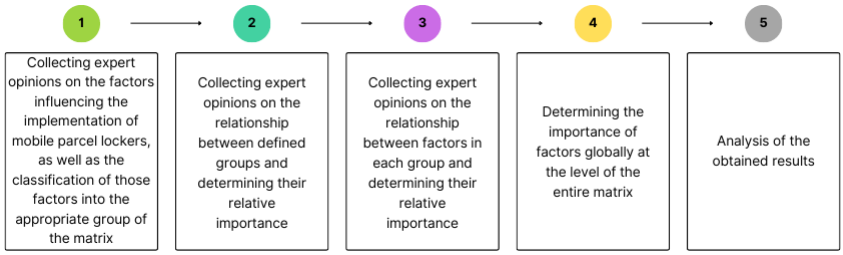

Fig. 1.
The Proposed Methodology

3. Results

In the research participated 10 experts from the postal traffic field. First, expert opinions were collected on influential factors related to the implementation of MPL within the domestic postal market, based on which a corresponding matrix was formed. After that, according to Saaty's scale of comparison, the experts evaluated the relationships between the defined groups, and then the relationships between the factors in each of the groups.

The created matrix with associated influencing factors is shown below (Figure 2).

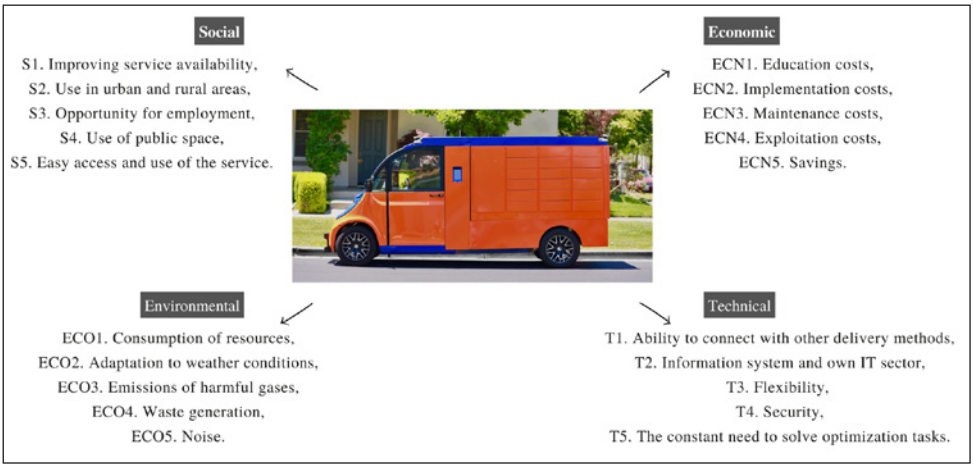

Fig. 2.
The Matrix of Influencing Factors

3.1. Social Factors

The usage of mobile parcel lockers affects the improvement of the availability of postal services. Namely, the availability of MPL could be 24/7, and on the other hand, their mobility would lead to physical proximity to users. The existence of MPL in the system and the corresponding applications also leads to the improvement of business efficiency, because it ensures that users can monitor its movement and thus plan a delivery or pickup of the shipment, as well as redirect their shipments to them in advance or later so that in this way the number of failed deliveries can be significantly reduced. MPLs are suitable for use in a variety of environments. Due to many user requests, the justification of the model is easier to see in urban areas, however, even for the dispersed structure of requests in rural areas, the observed application of MPL can be a suitable solution. In addition to the high level of autonomy in serving users, for the operation of mobile parcel lockers, the participation of workers would be necessary primarily in the tasks of operating parcel lockers, monitoring, maintenance, customer support, etc. In this way, the implementation of the system of MPLs can be a chance for the employment of new workers. The functioning of the system of mobile parcel lockers implies their participation in traffic because during exploitation they move on the appropriate route. At defined locations, MPLs are positioned and serve users. Using public resources, the functioning of the system can have a negative impact on residents who are outside the focus of the postal service. On the other hand, access to mobile parcel lockers is not significantly different from classic ones, so any user with previous experience can easily use them. The instructions for use would be contained on the MPL itself and within the accompanying application, whose interface would certainly be adapted to the average user.

3.2. Economic Factors

The introduction of technology implies the education of employees. This process is particularly important if new workers are employed in the system. Education involves costs, regardless of whether it is carried out by internal personnel or external collaborators. Very important costs are investment costs. The implementation of a system of MPLs requires certain costs, both for the procurement of parcel lockers and accompanying software, the creation of a user application, and the provision of other necessary equipment and infrastructure. In addition to the mentioned costs, maintenance costs are also significant. They are indispensable, because the smooth functioning of the system directly depends on timely and responsible maintenance, and therefore the level of service for the end user. Costs related to work, consumables during work, as well as fuel, belong to the group of operating costs. In systems that function daily, they are very important, because they are also generated daily. The application of parcel lockers can also bring savings to the company. Savings represent one of the indicators of the success of the system. MPLs can serve many users in all three shifts, if they are managed in an adequate way, which is greatly contributed by the information obtained through the application and the information system. Service costs per shipment become lower in this way.

3.3. Environmental Factors

Environmental factors in this case include a group of five isolated factors. They relate to the impact of the implementation and exploitation MPLs on the environment. It is necessary to consume electricity, as well as fuel and other raw materials. It is desirable to examine the impact of system implementation on emissions of harmful gases and waste generation, as one of the main indicators of environmental impact. One more negative impact of the MPLs system on the environment is the possibility of noise generation.

When it comes to systems that are exposed to extreme impacts, their ability to adapt is important. In the case of MPLs due to different circumstances, it is necessary to analyze the response of the system due to different weather conditions. The reason is the fact that weather conditions affect the traffic conditions, as well as the user's decisions on how to get to the parcel locker.

3.4. Technical Factors

Factors from this group refer to the technical performance of the system. As it is a system that responds to a wide range of many user requests, it must have a certain level of flexibility, as well as the ability to easily connect to other ways of performing the service. The goal is to satisfy the needs of the user. Many shipments transit through the extensive network of delivery systems, so there is a high chance of breaching their security. Companies must ensure the security of the service on several levels, to prevent damage to shipments, their enslavement, etc. One of the essential conditions for the implementation of the MPLs system is the existence of an IT infrastructure and IT sector. A very important fact related to the efficient functioning of the mobile parcel locker system is the optimization of its servicing following the user's requirements. Namely, creating the routes that the parcel machine will take, at which locations it will serve users and at what time, are the most important tasks that must be solved in real-time.

3.5. Determining the Relative Importance

The results obtained by implementing the proposed procedure based on the AHP method are presented below.

3.5.1. Determining the Relative Importance of Groups

In this phase, each of the experts performed 6 comparisons of the relationship between the groups, which makes a total of 60 comparisons. Table 1 shows the processed results.

Table 1
A Pairwise Comparison of Groups

Groups	S	ECN	ECO	T
S	1.000	1.128	0.939	1.389
ECN	0.887	1.000	0.740	0.885
ECO	1.065	1.351	1.000	0.671
T	0.720	1.129	1.490	1.000

By implementing the proposed procedure based on the AHP method, we obtained the following results (see Table 2). The results show that special attention should be paid to the groups of social and technical factors, but also that the group of environmental factors has an approximate importance, while the group of economic factors has a less pronounced importance. During the comparison, the experts satisfied the principle of consistency.

Table 2
The Results of Groups' Comparison

Group	S	ECN	ECO	T
Importance degrees	0.274	0.215	0.248	0.263

3.5.2. Determining the Most Influential Factor in the Group Social – S

Group S contains 5 factors. The experts performed a total of 100 comparisons, and the processed results are shown in Table 3.

Table 3
A Pairwise Comparison of Factors in the Group Social – S

Factors	S1	S2	S3	S4	S5
S1	1.000	1.162	2.048	1.490	1.349
S2	0.860	1.000	1.282	1.374	0.719
S3	0.488	0.780	1.000	0.907	0.626
S4	0.671	0.728	1.103	1.000	0.836
S5	0.741	1.390	1.597	1.196	1.000

By implementing the proposed procedure based on the AHP method, we obtained the following results (see Table 4). The results show that the most important factors are S1 (Improving service availability) and S5 (Easy access and use of services). The principle of consistency is satisfied.

Table 4

The Relative Importance of Factors in the Group Social – S

Factors	S1	S2	S3	S4	S5
Importance degrees	0.267	0.200	0.143	0.166	0.224

3.5.3. Determining the most Influential Factor in the Group Economic - ECN

Group ECN contains 5 factors also, and the processed results are shown in Table 5.

Table 5

A Pairwise Comparison of Factors in the Group Economic - ECN

Factors	ECN1	ECN2	ECN3	ECN4	ECN5
ECN1	1.000	0.749	0.699	0.608	1.029
ECN2	1.335	1.000	1.597	0.860	0.664
ECN3	1.431	0.626	1.000	0.780	0.652
ECN4	1.644	1.162	1.282	1.000	1.297
ECN5	0.972	1.506	1.534	0.771	1.000

By implementing the proposed procedure, we obtained the following results (see Table 6). The results show that the most significant factors are ECN4 (Exploitation costs) and ECN5 (Savings). The principle of consistency is satisfied.

Table 6

The Relative Importance of Factors in the Group Economic - ECN

Factors	ECN1	ECN2	ECN3	ECN4	ECN5
Importance degrees	0.159	0.205	0.169	0.245	0.222

3.5.4. Determining the most Influential Factor in the Group Environmental - ECO

Group ECO contains 5 factors. The experts performed a total of 100 comparisons, and the processed results are shown in Table 7.

Table 7

A Pairwise Comparison of Factors in the Group Environmental - ECO

Factors	ECO1	ECO2	ECO3	ECO4	ECO5
ECO1	1.000	0.679	0.561	1.490	0.826
ECO2	1.473	1.000	0.644	1.374	1.578
ECO3	1.783	1.552	1.000	0.907	1.835
ECO4	0.671	0.728	1.103	1.000	0.561
ECO5	1.210	0.634	0.545	1.783	1.000

By implementing the proposed procedure based on the AHP method, we obtained the following results (see Table 8). The results show that the most significant factors are ECO3 (Emissions of harmful gases) and ECO2 (Adaptation to weather conditions). The principle of consistency is satisfied.

Table 8
The Relative Importance of Factors in the Group Environmental - ECO

Factors	ECO1	ECO2	ECO3	ECO4	ECO5
Importance degrees	0.165	0.221	0.269	0.161	0.184

3.5.5. Determining the Most Influential Factor in the Group Technical – T

Group T contains 5 factors. The experts performed a total of 100 comparisons, and the processed results are shown in Table 9.

Table 9
A Pairwise Comparison of Factors in the Group Technical - T

Factors	T1	T2	T3	T4	T5
T1	1.000	1.162	2.048	1.490	0.826
T2	0.860	1.000	0.719	0.860	0.571
T3	0.488	1.390	1.000	0.907	0.626
T4	0.671	1.162	1.103	1.000	0.836
T5	1.210	1.750	1.597	1.196	1.000

By implementing the proposed procedure, we obtained the following results (see Table 10). The results show that the most significant factors are T5 (The constant need to solve optimization tasks) and T1 (Ability to connect with other delivery methods). The principle of consistency is satisfied.

Table 10
The Relative Importance of Factors in the Group Technical - T

Factors	T1	T2	T3	T4	T5
Importance degrees	0.244	0.155	0.163	0.182	0.256

3.5.6. Determining the Global Importance of Factors

Based on the results of the previous stages of application of the proposed model, obtained importance of groups and factors within those groups, it is possible to calculate the importance of each factor on the level of the entire matrix. Table 11 shows the results of the global importance of the factors. Based on the obtained results, it can be concluded that five factors stand out: S1 (Improving service availability), ECO3 (Emissions of harmful gases), T5 (The constant need to solve optimization tasks), T1 (Ability to connect with other delivery methods) and S5 (Easy access and use of services). These factors, based on the opinion of

experts, represent the most significant influential factors that can be linked to the implementation and use of mobile parcel lockers.

Table 11
The Global Importance of Factors

Groups	Factors	Importance of factors	Importance of groups	Global importance of factors
S	S1	0.267	0.274	0,073
	S2	0.200		0,055
	S3	0.143		0,039
	S4	0.166		0,046
	S5	0.224		0,061
ECN	ECN1	0.159	0.215	0,034
	ECN2	0.205		0,044
	ECN3	0.169		0,036
	ECN4	0.245		0,053
	ECN5	0.222		0,048
ECO	ECO1	0.165	0.248	0,041
	ECO2	0.221		0,055
	ECO3	0.269		0,067
	ECO4	0.161		0,040
	ECO5	0.184		0,046
T	T1	0.244	0.263	0,064
	T2	0.155		0,041
	T3	0.163		0,043
	T4	0.182		0,048
	T5	0.256		0,067

Circumstances today often prevent people from using postal services at a place and time that suits them. Namely, the potential user is often unable to use the services when they are available due to business or private obligations. The use of classic parcel lockers in this case is a good solution, because they improve time availability, while the use of mobile parcel lockers leads to an improvement in territorial availability as well. In the conditions of many requests for postal services and at the same time a heavy load on city roads, it can be concluded that the application of MPLs that can be "communicated" and that can be monitored through the application, is a good solution. By applying such a system, the number of trips by the user to use the service, and therefore the emission of harmful gases, is reduced. Users are allowed to access the parcel locker even at unpopular times during the 24 hours, i.e., when there is no traffic congestion. Driving in such conditions is significantly more economical, and therefore has a smaller negative impact on the environment. For the efficiency of the mobile parcel locker system to be at a high level, it is necessary to continuously solve a series of optimization tasks. Some of them are defining the route that the parcel locker will take, at which locations it will stay, in which periods of the day, etc. One of the additional tasks is optimization when connecting with other types of delivery. This is also a significant possibility of the system, primarily for the reason of organizing efficient delivery in the wider observed territory, where there are or it is possible to implement other types of delivery, such as traditional, autonomous vehicles, drones, etc. From the user's point of view, in addition to the safe and fast transfer of shipments, the complexity factor of using the

service is also very important. The principle of access to the MPL is almost the same as compared to the classic one. In addition to the basic functionality, the application should provide users with more value and some additional possibilities compared to conventional access to the service. Here we mean the possibility of monitoring the status of the parcel machine, i.e., its current location, as well as the plan of movement in the coming period. This information provides the user with the possibility of planning the use of services and organization in time.

4. Conclusion

Under the influence of the wave of e-commerce, the number of shipments in the systems of postal companies is on the rise in recent years (Kosovac *et al.,* 2022). Along with the specific requirements from customers and legal restrictions, as well as a general trend of overcrowded cities with numerous vehicles on the streets (Šarac et al., 2022), it is a great challenge to efficiently organize a last-mile delivery phase. Following technological development, postal companies have managed to accept and develop different business models over time. The main subject of this work is the analysis of the implementation of a modern technological solution - mobile parcel lockers in the postal system. In cooperation with experts, a matrix of influential factors was formed, and groups and factors were evaluated. The results of the analysis indicate that for the implementation and use of mobile parcel lockers, of the 20 isolated influential factors, the most important are those related to improving availability, emission of harmful gases, optimization tasks, the ability to connect with other delivery methods and ease of use of the service. The application of mobile parcel lockers with the use of various functionalities of the application provides users with the opportunity to efficiently use postal services during the periods of the day and in the locations that suit them. Some recommendations for future research would be to expand the used methodology based on the AHP method with, for example, a fuzzy approach (Božanić *et al.,* 2015; Bobar *et al.,* 2020) or to further improve the technological process by introducing a mobile phone application for users to improve a relationship between customers' demands and mobile lockers locations.

References

Bobar, Z.; Božanić, D.; Djurić, K.; Pamučar, D. 2020. Ranking and Assessment of the Efficiency of Social Media using the Fuzzy AHP-Z Number Model - Fuzzy MABAC, *Acta Polytechnica Hungarica* 17(3): 43-70. doi: 10.12700/APH.17.3.2020.3.1.

Božanić, D.; Pamučar, D.; Bojanić, D. 2015. Modification of the analytic hierarchy process (AHP) method using fuzzy logic: Fuzzy AHP approach as a support to the decision making process concerning engagement of the group for additional hindering, *Serbian Journal of Management* 10(2): 151-171. doi: 10.5937/sjm10-7223.

Ćirović, G.; Pamučar, D.; Božanić, D. 2014. Green logistic vehicle routing problem: Routing light delivery vehicles in urban areas using a neuro-fuzzy model, *Expert Systems with Applications* 41(9): 4245-4258. doi: 10.1016/j.eswa.2014.01.005.

Dobrodolac, M.; Lazarević, D.; Švadlenka, L.; Blagojević, M. 2015. The impact of entropy on the efficiency of express courier systems, *Journal of Applied Engineering Science* 13(3): 147-154. doi: 10.5937/jaes13-8586.

Dobrodolac, M.; Lazarević, D.; Švadlenka, L.; Živanović, M. 2016. A study on the competitive strategy of the universal postal service provider, *Technology Analysis & Strategic Management* 28(8): 935-949. doi: 10.1080/09537325.2016.1180357.

Ghaderi, H.; Zhang, L.; Tsai, P. W.; Woo, J. 2022. Crowdsourced last-mile delivery with parcel lockers, *International Journal of Production Economics* 251: 108549. doi: 10.1016/j.ijpe.2022.108549.

Iwan, S.; Kijewska, K.; Lemke, J. 2016. Analysis of parcel lockers' efficiency as the last mile delivery solution–the results of the research in Poland, *Transportation Research Procedia* 12: 644-655. doi: 10.1016/j.trpro.2016.02.018.

Kosovac, A.; Muharemović, E.; Kosovac, M.; Kavran, Z.; Rakić, E.; Mostarac, K.; Blagojević, M. 2022. Impact of Covid-19 on the Logistics Sector of Public Postal Operators in The Western Balkans, *Science, Engineering and Technology* 2(2): 31–36. doi: 10.54327/set2022/v2.i2.45.

Lazarević, D.; Dobrodolac, M.; Švadlenka, L.; Stanivuković, B. 2020. A model for business performance improvement: a case of the postal company, *Journal of Business Economics and Management* 21(2): 564-592. doi: 10.3846/jbem.2020.12193.

Lazarević, D.; Švadlenka, L.; Radojičić, V.; Dobrodolac, M. 2020. New express delivery service and its impact on CO_2 emissions, *Sustainability* 12(2): 456. doi: 10.3390/su12020456.

Mizutani, F.; Uranishi, S. 2003. The post office vs. parcel delivery companies: competition effects on costs and productivity, *Journal of Regulatory Economics* 23(3): 299-319. doi: 10.1023/A:1023368327735.

Mostarac, K.; Kavran, Z.; Bešenić, V. 2021. Application of geographic information system for the postal network analysis, *Perner's Contacts* 16(1): 1-12. doi: 10.46585/pc.2021.1.1653.

Muharemović, E.; Čaušević, S.; Kosovac, A.; Baraković Husić, J. 2021. Cost and performance optimisation in the technological phase of parcel delivery–a literature review, *Promet-Traffic&Transportation* 33(1): 129-139. doi: 10.7307/ptt.v33i1.3439.

Peppel, M.; Spinler, S. 2022. The impact of optimal parcel locker locations on costs and the environment, *International Journal of Physical Distribution & Logistics Management* 52(4): 324-350. doi: 10.1108/IJPDLM-07-2021-0287.

Ralević, P.; Dobrodolac, M.; Marković, D. 2016. Using a nonparametric technique to measure the cost efficiency of postal delivery branches, *Central European Journal of Operations Research* 24(3): 637-657. doi: 10.1007/s10100-014-0369-0.

Saaty, T. L. 1977. A scaling method for priorities in hierarchical structures, *Journal of Mathematical Psychology* 15(3): 234-281. doi: 10.1016/0022-2496(77)90033-5.

Schwerdfeger, S.; Boysen, N. 2020. Optimizing the changing locations of mobile parcel lockers in last-mile distribution, *European Journal of Operational Research* 285(3): 1077-1094. doi: 10.1016/j.ejor.2020.02.033.

Schwerdfeger, S.; Boysen, N. 2022. Who moves the locker? A benchmark study of alternative mobile parcel locker concepts, *Transportation Research Part C: Emerging Technologies* 142: 103780. doi: 10.1016/j.trc.2022.103780.

Šarac, D.; Čačić, N.; Kopić, M.; Blagojević M. 2022. Reserve Delivery Parking Spots in Urban Areas, *Transportation Research Procedia* 64: 138-148. doi: 10.1016/j.trpro.2022.09.017.

Šarac, D.; Kopić, M.; Mostarac, K.; Kujačić, M.; Jovanović, B. 2016. Application of set covering location problem for organizing the public postal network, *Promet-Traffic&Transportation* 28(4): 403-413. doi: 10.7307/ptt.v28i4.1962.

Vrba, R.; Hruška, R.; Novotná, M. 2022. Parcel lockers in Pardubice, *Perner's Contacts* 17(1). doi: 10.46585/pc.2022.1.2301.

Wang, Y.; Bi, M.; Chen Y. 2020. A scheduling strategy of mobile parcel lockers for the last mile delivery problem, *Promet-Traffic&Transportation* 32(6): 875-885. doi: 10.7307/ptt.v32i6.3531.