Draft Method for Determining the Number of Checking Devices Utilized within the Regional Passenger Transport

Nacrt metode sredstava za provjeru broja putnika koja se koriste u regionalnom putničkom prijevozu

Ondrej Stopka
Department of Transport and Logistics
Institute of Technology and Business
České Budějovice, Czech Republic
e-mail: stopka@mail.vstecb.cz

Ján Ponický
Department of Rail Transport
Faculty of Operation and Economics of Transport and Communications
University of Žilina, Slovak Republic
e-mail: jan.ponicky@fpedas.uniza.sk

Mária Chovancová
Department of Rail Transport
Faculty of Operation and Economics of Transport and Communications
University of Žilina, Slovak Republic
e-mail: maria.chovancova@fpedas.uniza.sk

Vladislav Zitrický
Department of Rail Transport
Faculty of Operation and Economics of Transport and Communications
University of Žilina, Slovak Republic
e-mail: vladislav.zitricky@fpedas.uniza.sk

DOI 10.17818/NM/2016/SI23
UDK 656.021
Original scientific paper / *Izvorni znanstveni rad*
Paper accepted / *Rukopis primljen:* 23. 3. 2016.

Summary

The transportation purpose represents the most important objective of regional passenger transport. The decision on determining the way of the passengers checking is one of the attributes that needs to be considered in relation to the passengers transportation. This issue may be solved by utilizing the checking devices and their appropriate placement. Applying the checking devices inside the transport means represents the establishing the prerequisites for self-check-in method in terms of passengers checking. This article presents the overview of aspects affecting the number of checking devices utilized within the regional passenger transport. For instance: traveled distance, transport means velocity, transport means circuit period and other may be included among these aspects. In the particular article chapter, the method for determining the number of checking devices utilized within the regional passenger transport is outlined.

KEY WORDS

passengers checking
method
checking device
regional railway transport
passengers' transportation

Sažetak

Svrha prijevoza predstavlja najvažniji cilj regionalnog putničkog prijevoza.Odluka o tome kako odrediti način provjere putnika je jedan od atributa koji se trebaju uzeti u obzir u vezi s putničkim prijevozom. Ovo pitanje može se riješiti korištenjem sredstava za provjeru i njihova prikladnog primijenjivanja. Upotreba sredstava za primjenu u području transporta znači ustanovljavanje pretpostavki metode samoprocjene putnika. Ovaj članak predstavlja pregled aspekata koji utječu na broj sredstava provjere koja se koriste u regionalnom putničkom prijevozu. Na primjer: prijeđena udaljenost, brzina transportnog sredstva, razdoblje kruga transportnog sredstva i drugo mogu biti uključeni među ove aspekte. Poseban odjeljak opisuje metodu određivanja broja sredstava za provjeru koja se koriste u regionalnom putničkom prijevozu.

KLJUČNE RIJEČI

provjera putnika
metoda
sredstvo provjere
regionalni željeznički prijevoz
prijevoz putnika

1. INTRODUCTION

In the particular territory, regional transport and additional transport systems (suburban transport, urban mass passenger transport, etc.) enable to utilize one kind of the ticket when utilizing several modes of transport for passengers. The necessary matter is to solve the issues regarding the passengers checking. Checking system of passengers may be performed using the different checking types. One of the methods for realizing the passengers check-in is to apply the checking devices in the transport means. Applying the checking devices in the space of transport means represents the establishing the prerequisites for self-check-in method in terms of passengers checking.

The transport operator does not need to ensure the check personnel who are intended to control the ticket validity. In the case that self-check-in method is implemented, passengers have to check the ticket in the ticket checking device after entrance into the transport mean. The finances savings (personal costs) are the main advantages for the transport operator who uses the self-check-in devices [1-3].

2. DESCRIPTION OF THE SELF-CHECK-IN METHOD

Determination of the self-check-in method, according to the placement of checking devices in the particular transport mean, represents one type of such a method. For placing the checking device inside the transport means, the proximity of individual doors represents the most utilized space. [1], [3]

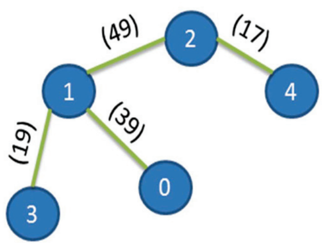
3. BACKGROUND FOR DETERMINATION OF THE NUMBER OF CHECKING DEVICES

Draft method for determining the particular number of specific checking devices is established on basis of the modeling the public transportation systems theory. The transportation systems theory determines the requests for the passengers' transportation (carriage). The background for determination of the desired number of checking devices includes [1], [2-4]:

- traffic network of the particular transport territory,
- matrix of distances.

3.1. Traffic network of the particular transport territory

Traffic network of the particular transport territory consists of the finite set of nodes and edges (see Figure 1). Edges of the traffic network (illustrated through green color) represent the oriented links between two nodes. Particular transport means are moving on these edges. Transport means are moveable elements in the traffic process (for instance: regional trains, suburban and urban busses, trolleys, etc.) [1], [4], [6].



Source: authors

Figure 1 The illustration of the traffic network of the particular transport territory

3.2. Matrix of distances

For all edges of traffic network, their long distance (*S*), capacity (*c*) and velocity (*v*) may be identified. Possibly, long distances of individual edges within the particular territory can be simply indicated creating the matrix of distances (see Table 1) [1], [4-6].

Table 1. Matrix of distances

j / i	0	1	2	3	4
0	0	39	88	58	105
1	39	0	49	19	66
2	88	49	0	68	17
3	58	19	68	0	85
4	105	66	17	85	0

Source: authors

4. DETERMINING THE NUMBER OF CHECKING DEVICES

The precise number of checking devices, which are to be applied in the transport means within the particular territory, depends on the following aspects [2], [5], [7]:

- layout of the doors within the transport means,
- configuration of the transport means,
- number of transport means.

4.1. Layout of the doors within the transport means

The particular transport means (their types, numbers, operation times, etc.) are designed by the defined rules. The technical layout of doors within the transport means influences the number of checking devices which are placed in the proximity of these doors. The mode of transport affects the technical layout of doors in the transport means as well [1], [7], [8].

Technical layout of installed doors may include:

- single-door layout - simple wing with the classic width,
- one and half door size layout - simple wing (wider than classic door),
- double-door layout - generally double-wings with the double-width.

Transport means equipped with a single-door layout are generally utilized within long-distance transportation. Long-distance transport means generate the frame of public mass passenger transport [2], [8]. This kind of transport means stops only on the main stations, therefore, the passengers' entries and exits from the transport mean is not so frequent. Single-door layout enables to enter (or exit) just for one passenger at the particular sequence of time. In this kind of layout, just one checking device in proximity of each door needs to be placed [2], [8-10].

Regional public passenger transportation is ensured by the regional transport means intended for shorter distances [8]. In this type, one and half door size layout is applied. This layout enables the rapid passengers' entry (exit) into the transport mean, however, just one passenger is allowed to get on at the particular sequence of time.

Another situation is realized within the suburban or urban mass passenger transport. Double-wings with the double-width are installed in suburban or urban transport means, and therefore, two passengers are allowed to enter (exit) into the transport mean at the particular sequence of time. Based on these assumptions, it is important to place two checking devices in proximity of each door. Transport means with this kind of doors layout are implemented within the suburban or urban mass passenger transport where the higher passengers' frequency is present [2], [9-12].

Based on the previous characteristics, the individual door layout coefficients (D_L) are assigned for the particular technical layout of doors within the transport means:

- D_L of single-door layout = 1,
- D_L of one and half door size layout = 1,
- D_L of double-door layout = 2.

4.2. Configuration of the transport means

Transport operator has to properly ensure the transportation performance on the particular territory. Transportation performance within the public mass passenger transport is ensured based on the orders from the particular public authority.

Transportation performance may be determined on the basis of traveled distance (pass.km) [5], [13]. The equation for its determination is as follows (1):

$$N_{tm.km} = \sum_{i=1}^{n} q_i * S_i \quad [tm.km] \tag{1}$$

where: $N_{tm.km}$ - the number of transport mean-kilometers [tm.km], q_i - number of transport means within the transport connection [transport means], S_i - traveled distance between two stations (stops) [km].

The transportation performance may also be determined on the basis of seat-kilometers [5], [13]. The equation for its determination is as follows (2):

$$N_{seat.km} = \sum_{i=1}^{n} K_i * S_i \quad [seat.km] \tag{2}$$

where: $N_{seat.km}$ - seat-kilometers [seat.km], K_i - transport mean capacity [seat], S_i - traveled distance between two stations (stops) [km].

On the basis of the share of these parameters, the average capacity of transport means, i.e. average transport means configuration, can be calculated (equation 3):

$$N_{transport\ means}^{\emptyset capacity} = \frac{N_{seat.km}}{N_{tm.km}} = \frac{\sum_{i=1}^{n} K_i * S_i}{\sum_{i=1}^{n} q_i * S_i} \ [seat.tm^{-1}] \tag{3}$$

where: $N_{transport\ means}^{\emptyset capacity}$ - average capacity of the transport means.

4.3. The number of transport means

The average capacity of transport means is not comprehensive factor for the determining the number of checking devices which need to be placed within the transport mean. The number of transport means, utilized in the context of transport services providing within the particular territory, is considered to be the next important factor (parameter) in the matter of determining the number of checking devices.

In the first phase, it is inevitable to set the operation time of the transport mean (transport mean hours) that specifies the time period of the transport mean operation activities in relation to the selected transportation performance section [4], [5], [13-15].

The equation for determining this parameter is as follows (4):

$$tm_h = \frac{\sum_{i=1}^{n} q_i * S_i}{c_p} [tm.hours^{-1}] \tag{4}$$

where: tm_h - transport mean hours [tm.hours^{-1}], c_p - circuit period [km.h^{-1}].

The circuit period of the transport means depends on the length of route section, traveling time and the time period spent in the station. In the station (stop), it is important to take into consideration the additional time period of operational preparation of the transport means (cleaning, operational maintenance, etc.) and the time of waiting for the next procedures [4], [5], [16].

The equation for determining the circuit period is as follows (5-8):

$$t_{t\,(0-1)} = (t_{t\,(0-1)} + (\tau_{r(0)} + \tau_{z(1)}) + t_{op(1)} + t_{w\,(1)}) \ [km.h^{-1}] \tag{5}$$

$$t_{t\,(1-0)} = (t_{t\,(1-0)} + (\tau_{r(1)} + \tau_{z(0)}) + t_{op(0)} + t_{w\,(0)}) \ [km.h^{-1}] \tag{6}$$

$$\sum T_s = n + t_s \tag{7}$$

$$c_p = \frac{2*S}{(t_{t\,(0-1)} + t_{t\,(1-0)}) + \sum T_s} \tag{8}$$

where: c_p - circuit period [km.h^{-1}], S - traveled distance [km], t_t - traveling time [min], τ_r, τ_z - the spread between the start and stop [min], t_{op} - time period of operational preparation [min], t_w - the time of waiting for the next procedures [min], $\sum T_s$ - the total stops time [min], n - the number of stops, t_s - stop time [min].

The circuit period of the transport mean may be determined utilizing the transport mean velocity. However, in this case, time period of operational preparation and the time of waiting for the next procedures are not taken into account. At the beginning of calculation, it is important to pre-determine the share of traveling time, time of maintenance and the time of waiting for the next procedures. Subsequently, the travel velocity is multiplied by this indicator and the circuit period is the outcome [5], [14], [16-18].

Using the following equations (9-11), transport means velocity, traveling schedule factor and the value of circuit period are determined:

$$V_{tm} = \frac{S}{t_t + (\tau_r + \tau_z) + t_w} \ [km.h^{-1}] \tag{9}$$

$$f_{sc} = \frac{t_t + t_{op} + t_w}{t_t} \ [-] \tag{10}$$

$$c_p = V_{tm} * \frac{1}{f_{sc}} \ [km.h^{-1}] \tag{11}$$

where: V_{tm} - transport mean velocity [km.h^{-1}], f_{sc} - traveling schedule factor [-].

The total number of transport means is determined as a portion of the transport mean hours and the operation time on the particular route part. It is also necessary to take into account the 15% reserve amount in the case of malfunctions (system failure, repairs, etc.).

The specific equation for determining the total number of transport means is (12):

$$N_{tm} = \frac{tm_h}{t} * R_e \tag{12}$$

where: N_{tm} - total number of transport means, tm_h - transport mean hours [tm.hours^{-1}], t - operation time [hour], R - amount of reserve [%].

Determining the total number of checking devices installed within the particular transport means is performed on the basis of number of transport means (structure of the transport connection), number of doors, door layout coefficients and the total number of transport means [5], [14], [17-19].

The equations for determining the total number of checking devices is as follows (13,14):

$$N_{\emptyset\ transport\ means} = \frac{N_{\emptyset\ transport\ means}^{\emptyset capacity}}{N_{\emptyset\ tc}^{\emptyset\ capacity}} \tag{13}$$

where: $N_{\emptyset\ transport\ means}$ - average number of transport means, $N_{\emptyset\ transport\ means}^{\emptyset capacity}$ – average capacity of transport means, $N_{\emptyset\ tc}^{\emptyset\ capacity}$ – average capacity of transport means within the transport connection.

$$N_{cd} = \left(\frac{\frac{\sum_{i=1}^{n} K_i * S_i}{\sum_{i=1}^{n} q_i * S_i}}{N_{transport\ means}^{\emptyset\ capacity}} * N_D * D_L \right) * \left(\frac{tm_h}{t} * R_e \right) \tag{14}$$

where: N_{cd} – the total number of checking devices [pcs], N_D - number of doors in transport means [pcs], D_L - door layout coefficients: for - single-door layout $D_L = 1$, one and half door size layout $D_L = 1$, double-door layout $D_L = 2$.

5. DRAFT METHOD APPLICATION ON THE PARTICULAR EXAMPLE

The draft method is applied on the particular route section within the particular territory in the Czech Republic. This rout section is included within the regional mass passenger transport. This section is located on south-west part of the Czech Republic in the South Bohemia region and its length is 40 km.

Public mass passenger transport is ensured by particular buss types. Considering the fact that this route section is included within the regional mass passenger transport on the particular territory, self-check-in method of passengers checking needs to be utilized. Based on this fact, the following question arises. How many checking devices need to be installed in the transport mean? The draft method can answer this question [19], [20].

5.1. The necessary attributes

Within the first phase of the draft method application, it is inevitably to identify the necessary attributes of the route section.

- the route section length - 80 km,
- the number of transport means within the transport connection - 8 pcs,
- the capacity of one transport mean - 93 seats.

The following calculations are necessary:

$$N_{tm.km} = \sum_{i=1}^{n} q_i * S_i = \sum_{i=1}^{8} 8 * 80 = 640 \quad [tm.km]$$

$$N_{seat.km} = \sum_{i=1}^{n} K_i * S_i = \sum_{i=0}^{n} (8 * 93) * 80 = 59\,520 \quad [seat.km]$$

$$N_{transport\ means}^{\emptyset capacity} = \frac{N_{seat.km}}{N_{tm.km}} = \frac{\sum_{i=1}^{8} K_i * S_i}{\sum_{i=1}^{8} q_i * S_i} = \frac{(8*93)*80}{8*80} = \frac{59520}{640} = 93\ [tm.seat^{-1}]$$

The number of transport means:

- the traveling time (0 - 1) - 50 min,
- the traveling time (1 - 0) - 54 min,
- the stop time (0 - 1) - 6 min,
- the stop time (1 - 0) - 10min,
- time for waiting for the next procedures - 30 min,
- time of maintenance - 30 min.

$$t_{t\,(0-1)} = \frac{\left(t_{t\,(0-1)} + t_{op(1)} + t_{w\,(1)} + \sum T_s\right)}{60} = \frac{(50+30+30+6)}{60} = 1{,}93\ h$$

$$t_{t\,(1-0)} = \frac{\left(t_{t\,(1-0)} + t_{op(0)} + t_{w\,(0)}\ \sum T_s\right)}{60} = \frac{(54+30+30+10)}{60} = 2{,}06\ h$$

$$c_p = \frac{S}{t_{t\,(0-1)} + t_{t\,(1-0)}} = \frac{80}{1{,}93+2{,}06} = 20{,}05\ km.h^{-1}$$

$$tm_h = \frac{\sum_{i=1}^{n} q_i * S_i}{c_p} = \frac{8*80}{20{,}05} = 31{,}92\ [tm.hours^{-1}]$$

The number of transport means within the transport connection:

$$N_{tm} = \frac{tm_h}{t} * R_e = \frac{31{,}92}{19{,}30} * 15\% = 1{,}90 = 2\ [transport\ means]$$

$$N_{cd} = \left(\frac{\frac{\sum_{i=1}^{n} K_i * S_i}{\sum_{i=1}^{n} q_i * S_i}}{N_{transport\ means}^{\emptyset\ capacity}} * N_D * D_L\right) * \left(\frac{tm_h}{t} * R_e\right) = \left(\frac{\frac{59520}{640}}{93} * 4 * 1\right) * \left(\frac{31{,}92}{19{,}30} * 15\%\right) = 8$$

In the decimals values, the decimal dots have to replace the decimal commas.

6. CONCLUSION

Determining the number of necessary checking devices installed in the transport means depends on the configuration of transport means within the transport connection, their numbers and technical doors layout of doors inside the individual transport means.

Door layout coefficients may be determined according to the configuration of the transport means doors. They can be determined on the basis of transport means operation in various types of mass passenger transport (long distance, regional, suburban and urban) as well. These coefficients are utilized for the calculation of the number of checking devices which are to be placed inside the transport means [5], [14], [20-22].

The transport operator is required to ensure the transportation performance on the basis of the transportation orders from the public authority, with his own transport means, in the entire particular territory. The share of these values is subsequently utilized in order to determine the average capacity of the transport means.

The number of transport means is set on the basis of transport means hours and transport means velocity. These values can calculate the operation time period within the particular territory. After all, the rapid passengers checking in the transport means can help to obtain the increased transportation time of the passengers [23].

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