METHODOLOGY OF TICKET MACHINE DESIGNING IN PASSENGER RAILWAYS VEHICLES

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Abstract: *The task of integrated transport system in passenger transport is connection between their other modes. One part of implementation of integrated transport system is set up the ticketing system for validation. This problem can solving by the ticket machines and their location. When ticket machines are located in vehicle, we create conditions for Self-Service System in public transport.*

The paper is focused on the description of factors, which influences number of ticket markers in railway passenger vehicles. For example these factors is circulation time of vehicles, transport distance, travel speed and etc. One part of paper includes the methodology of calculation the ticket markers for rail passenger vehicles.

KEYWORDS: INTEGRATED TRANSPORT SYSTEM, MARKING MACHINE, THE SELF-SERVICE SYSTEM, TRANSPORT TICKET VALIDATION

1. Introduction

Integrated transport system (ITS) allows passengers to use one ticket by travelling with all transport modes in integrated area. The important question by the ITS is to solve problems with service system of passengers. Service system of passenger can be in several forms. One of the ways to ensure passenger expedition is located the ticket machines to vehicles. When ticket machines are located in vehicle, we create conditions for Self-Service System in public transport. Carrier has not ensured a conductor that will be validating the travel ticket. When carrier is using Self-Service system, passenger must validate the travel ticket in ticket machines after entry into the vehicle. The advantage for carrier, which is using of Self-Service system, is low economic burden (personal costs).

2. Self-Service system

One form of Self-Service system is based on the location of ticket machines in vehicles. The most frequent place, when the ticket machines are located is the place near to door of vehicle. (Fig. 1).

Fig. 1 *Place for the ticket machine in vehicle*

Railway lines and vehicles with Self-Service system in use are identified by special symbol (Fig. 2). This system for passenger is known from public transport. The Passengers must buy transport ticket even before the boarding vehicle on. For passenger it is compulsory to validate transport ticket by ticket machine as soon as possible.

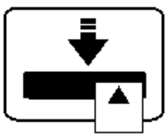

Fig. 2 *Pictogram of Self-Service system*

3. Basis for determining the number of ticket machine

Methodology for calculation to required number of marking machines is based on the theory of modelling the transport systems in passenger transport. The modelling the transport system imposes requirements for the relocation of persons, i.e. transport elements – passengers. The bases for determining the required number of marking machines are:

- Transport network of integrated area
- Distance matrix.

3.1 Transport network of integrated area

Transport network of integrated area is composed of a finite set of nodes and edges (Fig.3). Edges on the transport network (marked by green colour) create oriented connections between two nodes. On these edges are moving ensembles. Ensembles are moveable objects in the transport process (for example train is ensemble).

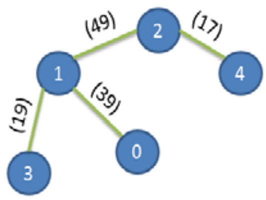

Fig. 3 *Transport network of integrated area*

3.2 Distance matrix

For all edges of transport network we can define its long distance (S), capacity (c) and speed (v). Long distance of single edges in integrated area is possible record write down in the distance matrix. (Tab. 1).

Table 1: *Distance matrix*

i/j	***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**

4. The calculation the required number of marking machines

The exact number of marking machines, which will be equipped ensembles in the integrated area, depends on the following factors:

- the design of the door on the set,
- composition sets (train composition),
- the number of sets.

4.1 The design of the door on the set

Set is a dose (rail vehicle) that is creating by the defining rules. When replenish a dose with appointed objects, we are create the ensemble.

The technical design of the door on the set affects the number of marking machines, which are located near the door. Also type of transport influences the technical solution of door on the vehicle.

Technical solution of used doors can be divided:

- single door (Fig. 4) – simple wing with basic (standard) width,
- one and half size – simple wing (wider single doors),
- double doors (Fig. 5) – usually double wings with double width.

Vehicles are using on these type of transport:

- long distance transport,
- regional transport,
- sub-urban transport.

Set with single technical construction of door are mostly using on long distance transport. Long distance trains create the frame of rail passenger transport [1]. This type of train stops only on the main stations, therefore entrance and exit of passenger from vehicle is not often. Single construction of door allow to entrance (or exit) only one passenger at the same time. In this type of vehicle we must located one marking machines by every door.

Fig. 4 *Technical solution of single door*

Public transport is provided by regional trains to shorter distance [2]. In this case is technical construction of doors on a half size. This construction allow to faster entrance (exit) of passengers to vehicle, but only one passenger can boarding at the same time.

Another situation is in the sub-urban transport. Technical construction of door in sub-urban trains is double and two passenger can entrance (exit) to vehicle at same time. Based on this situation it is necessary located two marking machines at the door. Sets with this type of doors is provided on the regional trains, where is high frequency of passengers.

Fig. 5 *Technical solution of double doors*

Based on the technical contraction of door on the vehicle are determined the coefficients technical solutions of doors (C_D). Tab. 2

Table 2: *Coefficients technical solution of doors*

Solutions of doors	C_D
Single door	1
One and half size	1
Double doors	2

4.2 Composition sets (train composition)

Railway undertaking must provide on the integrated area transport performance sufficiently. Transport performance in public transport is established based on order from public authority.

Traffic performance is determined on the basis of train-kilometers (ordering unit) [3]. The formula for its calculation is following:

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

where:

$N_{train.km}$ *train-kilometers [train.km],*
q_i *number of sets [train],*
S_i *distance between two nodes [km].*

The transport performance is determined on the basis of seat-kilometers [3]. The formula for its calculation is following:

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

where:

$N_{seat.km}$ *seat-kilometers [seat.km],*
K_i *capacity of sets [seat],*
S_i *distance between two nodes [km].*

Based on the proportion of these indicators is determinate average capacity of ensembles, i.e. average composition of ensembles.

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

where:

$N_{ensembles}^{\emptyset\ capacity}$ *average capacity of ensembles.*

4.3. The number of ensembles

The average capacity of ensembles (trains) is not sufficient indicator the number of marking machines, which carrier need to place in the vehicle. The next necessary indicator is number of ensembles (trains), which railway undertaking will be provided transport serviceability on the integrated area.

At first, it is necessary to determine the train hours that specify what is the time period of serviced activity in conditions of selected line section performance.

Calculation formula is:

$$T_h = \frac{\sum_{i=1}^{n} q_i * S_i}{V_{oe}} [train.hours^{-1}] \qquad (4)$$

where:

T_h *train hours [train.hours^{-1}],*
V_{oe} *the rate of turnover ensembles [km.h^{-1}].*

Turnover rate of ensemble depends on the length of line section, travel time and well time in the station. In terminal station (terminus) it is needed to calculate with an additional time of operational preparation of vehicle (cleaning, refilling of water, etc.) and the waiting time for the next performance (Fig. 6).

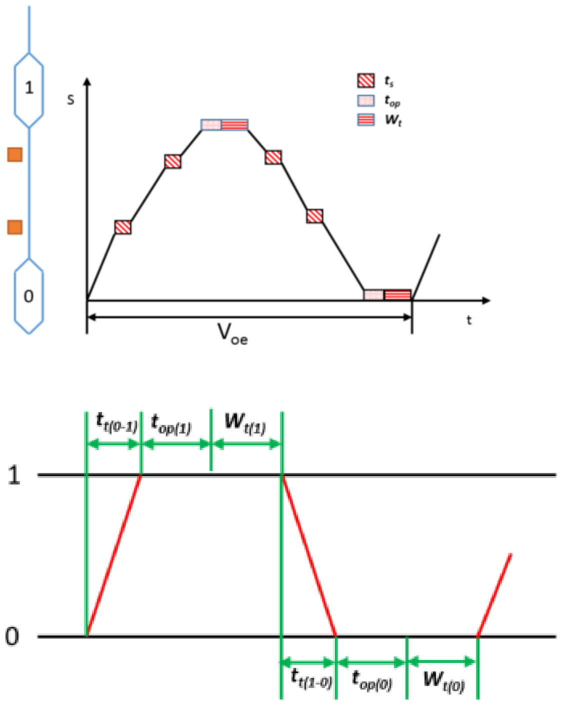

Fig. 6. *The ensembles turnover period*

Formula for calculating the rate of turnover follows:

$$V_{oe} = \frac{2 * S}{(t_{t\,(0-1)} + t_{t\,(1-0)}) + \sum T_s} \; [km.h^{-1}] \qquad (5)$$

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

$$t_{t\,(1-0)} = (t_{t\,(1-0)} + (\tau_{r(1)} + \tau_{z(0)}) + t_{op(0)} + W_{t\,(0)}) \; [km.h^{-1}] \qquad (7)$$

$$\sum T_s = n + t_s \, [min] \qquad (8)$$

where:

V_{oe} *the rate of turnover ensembles [km.h^{-1}],*
S *long distance [km],*
t_t *travel time [min],*
τ_r, τ_z *margin to start and stop [min],*
t_{op} *the time of operational preparation of ensembles [min],*
W_t *the waiting time for the next performance [min],*
$\sum T_s$ *sum time stay [min],*
n *number of nodes,*
t_s *times stay[min].*

Turnover rate of ensembles can also be calculated using a traveling speed. However, in this case, the time of operational preparation of vehicle and waiting times is not considered. At the beginning of calculation it is necessary to pre-calculate proportion of travel time, cleaning time and the waiting time for the next performance. Consequently, the cruising (traveling) speed is multiplied with this factor that results in a turnover rate of ensembles.

The following formulas are:

$$V_{ts} = \frac{S}{t_t + (\tau_r + \tau_z) + W_t} \; [km.h^{-1}] \qquad (9)$$

$$K_{tt} = \frac{t_t + t_{op} + W_t}{t_t} \; [-] \qquad (10)$$

$$V_{oe} = V_{ts} * \frac{1}{K_{tt}} \; [km.h^{-1}] \qquad (11)$$

where:

V_{ts} *travel speed of ensembles [km.h^{-1}],*
K_{tt} *coefficient of timetable [-].*

The total amount of ensembles is set as the ratio of the train hours and operating time on the line section. It is very important to take in consider the reserve of value 15% in case of disturbances (disorders, reparations etc.)

The formula is:

$$N_e = \frac{T_h}{t} * R \;\; [total\ amount\ of\ ensembles] \qquad (12)$$

where:

N_e *total amount of ensembles,*
T_h *train hours [train hours],*
t *operation time [hour],*
R *reserve [%].*

Total number of ticket marker in vehicle it is provided on the base number of vehicle (train consist structure), number of doors, coefficient doors and total amount of vehicle.

The formula is:

$$N_{\emptyset\ ensembles} = \frac{N^{\emptyset capacity}_{\emptyset\ ensembles}}{N^{\emptyset\ capacity}_{\emptyset\ sets}} \; [average\ of\ ensembles] \qquad (13)$$

where:

$N_{\emptyset\ ensembles}$ *average of ensembles,*
$N^{\emptyset\ capacity}_{\emptyset\ ensebles}$ *average of capacity ensembles,*
$N^{\emptyset\ capacity}_{\emptyset\ sets}$ *average of capacity sets.*

$$N_{tm} = \left(\frac{\frac{\sum_{i=1}^{n} K_i * L_i}{\sum_{i=1}^{n} q_i * L_i}}{N^{\emptyset\ capacity}_{ensembles}} * N_D * C_D \right) * \left(\frac{\frac{\sum_{i=1}^{n} q_i * L_i}{V_{oe} * \frac{1}{K_{tt}}}}{t} * R \right) \qquad (14)$$

where:

N_{tm} *number of ticket marker [number],*
N_D *number of doors in ensembles [number],*
C_D *coefficients technical solution of doors:*
single door C_D = 1,
One and half size C_D = 1,
double doors C_D = 2.

5. Conclusion

Determination of marking machines depends on composition of ensembles, their numbers and technical constructions of doors in sets (vehicles).

Coefficients technical solutions of doors were determinate according to construction of doors on the vehicle. They also were determinate based on the operation of vehicle in different types of transport (long distance, regional and sub-urban). These coefficients were used to calculation to the number of marking machines, which are located in the vehicles.

Carrier is obliged to provide transport performance based on the order by public authority, with own ensembles (vehicles), on the whole integrated area. Proportion of these values (based on train and seat kilometres) gives the average capacity of the ensembles (trains).

The number of ensembles (trains) is based on the train hours and return speed of set. These values determines of time period transport serviceability of the territory. Faster transport serviceability of the integrated area we achieve with increasing of return speed of sets.

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