Revised Estimation of Public Railway Infrastructure Line Capacity: Lithuanian Case

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Abstract. The problematic of determination of maximum capacity of Lithuanian Railway lines is considered is this article. Maximum capacity considered the largest number of trains that could run over a railway line, during the scheduled time interval. At the same time, the train traffic should be ensured in a strictly perfect, mathematically defined environment, with the trains running permanently and ideally at minimum headway, i.e., keeping time-based distance between two consecutive trains. Current applied calculation methods and the means of Lithuanian train traffic arranging are revised by estimating the railway traffic irregularity due the features of technical equipment: traction vehicles, signalling, automatic, track, catenary, etc. The maximum potential capacities of three problematic lines of Lithuanian Railways are estimated taking into account the type and power of freight locomotives. Considered railway lines are: "Livintai – Gaižiūnai", "Plungė – Šateikiai" and "Pagėgiai – Tauragė – Viduklė". Finally, basic conclusions and recommendations are given.

Keywords: Railway transport · Line capacity · Traffic schedule · Period · Time interval · Consecutive trains

1 Problematic of Ensuring the Railway Capacity

The railway transport sector consists of railway infrastructure (railway, power supply and signalling/automatic) and rolling stock fleet (rolling stock, road vehicles, depots, etc.). The capacity of a railway line is the maximum number of trains or pairs of trains of a specified mass that can be passed during a unit of time (day, hour, day) ensuring absolute traffic safety. The available technical means of traffic organization (equipment), the type and power of the rolling stock used, technologies and established methods of train traffic organization (e.g., type of traffic schedule) are evaluated.

Many researchers consider the problematic of effective using of railway capacity in different countries. The in-depth research of the main factors affecting railway capacity is being carried out on a few Spanish railway infrastructures [1]. The results exemplify how the capacity diverges with factors such as train speed, arranged stops, train heterogeneity, distance between rail signals, and traffic timetable consistency [1, 10]. Real data from the Swedish rail network, train operation and delays were used by Anders to analyse how different factors influence available capacity and train delays [2]. The second approach of

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this researcher was the railway experiments by using simulation tool RailSys, especially the analysis revealed an in-depth understanding of the mechanisms of railway operation on double-track lines. Other paper describes how the UIC 406 method it is expounded in Denmark [8, 9]. The relationship between train delay, traffic volume and train type heterogeneity was investigated in a series of experiments using simulation analysis of trains operating on a single-track rail lines was considered by Dingler [5]. The density of railway level crossings has a considerable influence on the capacity of railway lines due to the speed limitation in them [3, 4].

Theoretical capacity is the number of trains that could run over a route, during a specific time interval, in a strictly perfect, mathematically generated environment, with the trains running permanently and ideally at minimum headway (i.e., temporal interval between two consecutive trains). The main disadvantage of the current Lithuanian railway transport infrastructure is the insufficiency of two-track railways in the entire network. In 2020 two-track lines of Lithuanian Railways accounted for only 23% of the entire national railway network. For this reason, the passing oncoming trains and free passing of slower moving trains raise complications.

The aim of this study was to reveal the inaccuracies of determination the capacity of the lines by Lithuanian Railway Undertaking (thereafter – RU) and to propose the methods of calculating the maximum capacity of the lines and the ways of its realization. The new approach proposed by Author to ensure enlarging the capacity of railway lines is relying on freight locomotive dynamic features: acceleration and potential speed considering the profile of track instead of scheduled time periods.

2 Methodology of Determination of Railway Line Capacity

The capacity of a railway line is the maximum number of freight trains (pairs of trains) of the specified mass and length, which can be passed through this railway line per time unit (day, hour), taking into account the technical equipment of the railway line and the way train traffic is organized. It is possible to extract the available capacity, i.e., the one that is currently available and the necessary capacity required to provide the expected traffic volumes in the nearest future.

Capacity is determined by dividing the time of day available for train traffic by the schedule period. Automation and centralisation of operations could bring useful capacity closer to the maximum calculated, or even to their maximum level. Factors that affect capacity include:

1. rolling-stock;
2. locomotive power (acceleration and potential speed);
3. train length;
4. brake distance;
5. automation and signalling equipment are used in stations and lines;
6. making of schedules (using a certain type of schedule);
7. development of the infrastructure at the stations;
8. availability of platforms;
9. development of railway infrastructure;

10. development of station switcher yard;
11. types of switchers that are used in stations;
12. train traffic planning and organization processes, etc.

The map of the network of Lithuanian Railway lines is presented in Fig. 1.

Fig. 1. The network of public lines of Lithuanian Railways.

The concluding capacity of the line is determined by the capacity of the limiting line. The limiting line is defined as follows:

1. The largest capacity line is determined, i.e., line in which the sum of the even and odd train schedule period is the largest.
2. The scheme for passing trains at the largest line is chosen, according to which the train schedule period is the smallest.

According to Fig. 2 it can be seen that the capacity is limited at three lines: "Livintai – Gaižiūnai", "Plungė – Šateikiai" and "Pagėgiai – Tauragė – Viduklė". It should be noted that the main factor reducing capacity is single-track lines in the sectors "Vilnius – Klaipėda" and "Klaipėda – Pagėgiai – Radviliškis".

The capacity of railway lines and stations are calculated according to the Lithuanian Railway methodology for calculating the capacity of railway lines and stations [6, 7]. Technological processes and technical data are also taken into account. The capacity of individual railway lines is determined by the following elements:

1. lines – lines limiting the capacity of the railway sector;

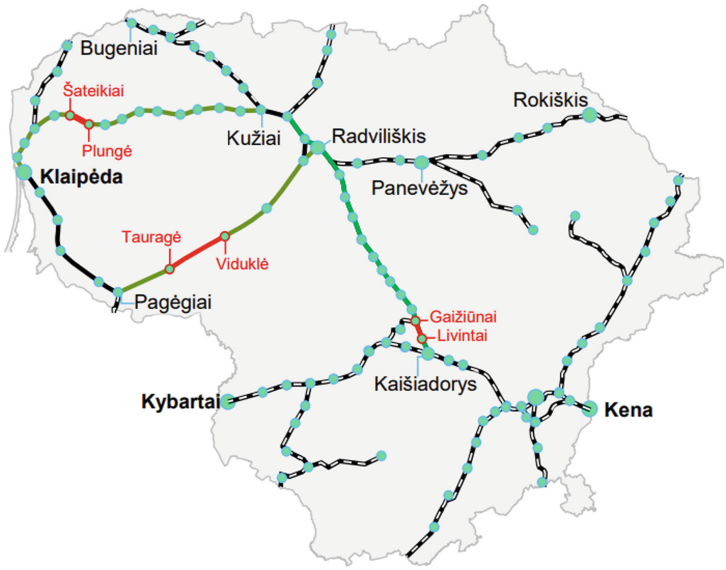

Fig. 2. Three problematic Lithuanian Railway sections: "Kaišiadorys – Radviliškis", "Kužiai – Klaipėda" and "Radviliškis – Pagėgiai" [7].

2. stations – capacity of arrival and departure tracks and switchers;
3. power supply equipment of electrified lines – data of the power supply traction system.

3 Calculations of Line Capacities and Results

3.1 Definition of Traffic Scheduled Periods on Lines

A schedule period is considered to be the time that a railway line is occupied by a group of trains, characteristic of a certain schedule type. It is usually chosen from the four options of passing trains (see Fig. 3), according to which the period T is calculated. These four schemes show different options of possible passing of opposing freight trains through the limiting railway line. The lowest value of scheduled period for calculating the capacity was selected. When drawing up the train traffic schedule, it is necessary to provide for the passage of trains through the limiting line in accordance with the scheme that ensures the highest efficiency.

The line capacity is calculated with a unified mass of the train:

1. The mass of odd direction freight trains is equal to 6,000 t.
2. The mass of even direction trains is equal to 2,500 t.

The unified mass of freight trains is selected from 2020/2021 of the freight train traffic schedule of RU. Schemes of passing trains through the lines of limited capacity are shown in Fig. 3.

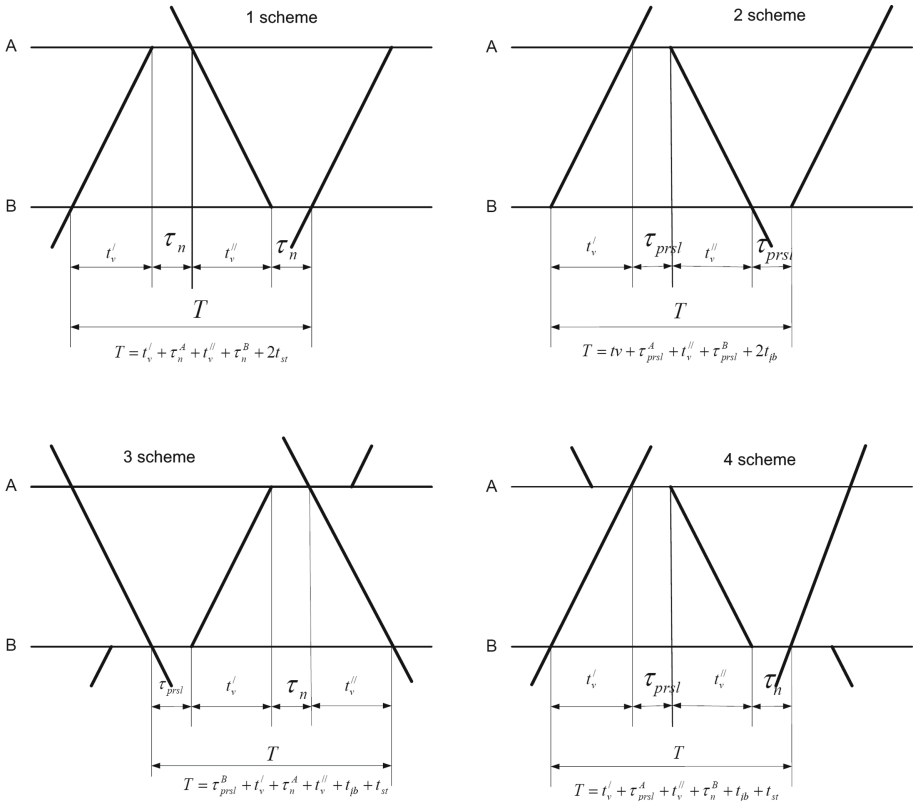

Fig. 3. Schemes of passing trains through the lines of limited capacity: T – period of train traffic schedule, min.; $t_v^{'}$ and $t_v^{''}$ – train running time without braking and acceleration, min.; t_{st} – train braking time, min.; t_{jb} – train acceleration time, min.; T_n – train arriving interval at considering stations A and B, min.; T_{prsl} – train overtaking interval in considering stations A and B, min.

It is also assumed that the throughput is calculated for the main series of freight locomotives used in Lithuanian Railways: 2M62M and SIEMENS ER20CF. The technical characteristics of these locomotives were used in the calculations.

At the railway line "Livintai-Gaižiūnai" the shortest time period is obtained by organizing train traffic according to the 3rd scheme (Fig. 3), and at the line "Plungė – Šateikiai" and "Viduklė – Tauragė" according to the 2nd scheme. The capacity indicators of railway line depend on the types of signalling, automatic and blocking equipment used to manage train traffic at that line, train movement speeds and principles of traffic organization.

3.2 Capacity of Railway Line "Viduklė–Tauragė"

The length of this single-track line is 42.3 km. A semi-automatic blocking is used to organize train traffic, i.e., there can be only one train at a line. Both Viduklė and Tauragė

stations are equipped with electrical centralization of switches and signals. The permitted speed of freight trains at this line is 80 km/h.

The maximum capacity of the line "Viduklė –Tauragė" is calculated according to the Formula (1). It was evaluated the main criteria of the components of development of the Lithuanian Railway technological process [10]:

$$N = \frac{(1440 - t_{tech}) \cdot \alpha_p}{T}; \tag{1}$$

where 1440 – number of minutes per day; t_{tech} – technology breaks of train traffic, min.; α_p – reliability coefficient, estimating the traffic irregularity due the fails of technical equipment (signalling, automatic, track, catenary, etc.); T – period of train traffic schedule, min.

The duration of the technological traffic break on single-track lines is 60 min. The reliability coefficient is 0.96. In this case, the capacity of the line is $N = 13$ pairs of trains, i.e., 13 even and 13 odd trains. Carrying trains with 2M62M or 2ER20CF locomotives and properly repaired infrastructure tracks would increase the capacity of the line up to $N = 16$ pairs of trains.

The throughput of the railway line "Viduklė–Tauragė" is presented in Fig. 4.

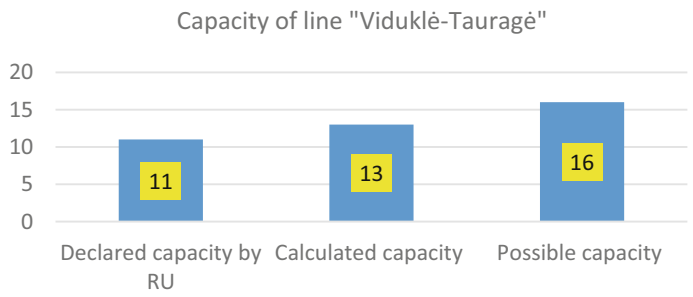

Fig. 4. The capacity of the line "Viduklė – Tauragė" in pairs of trains.

3.3 Capacity of Single-Track Line "Plungė – Šateikiai"

The line "Plungė – Šateikiai" is the limiting line of the railway section "Kužiai – Klaipėda". The line is 13.9 km length. Both stations bordering the line are equipped with microprocessor centralization of switchers and signals. An automatic blocking is used to manage train traffic on the line. This means that the blocks separating the trains from each other are limited by the line traffic lights. The maximum permitted speed for freight trains at this line is 90 km/h.

The line "Plungė – Šateikiai" is single-track and equipped with an automatic blocking, so the capacity is calculated according to the Formula (2) [10]:

$$N = \frac{K \cdot (1440 - t_{tech}) \cdot \alpha_p}{(K - (K-1) \cdot \alpha_{pp}) \cdot (t' + t'' + T_a + T_b) + (K-1) \cdot (I_t' + I_t'') \cdot \alpha_{pp}}; \tag{2}$$

where α_{pp}– set coefficient, equal to proportion of number of trains running in the set and the total number of passing trains; t' and t'' – running time of trains on a line, min.; $I_t^{'}$ and $I_t^{''}$ – interval between the train sets running on even and odd direction, respectively, min.; K – number of trains in the set; T_a and T_b – periods of train traffic schedule, respectively stations A and B, min.

The maximum calculated capacities of the railway line "Plungė – Šateikiai" are shown in Fig. 5.

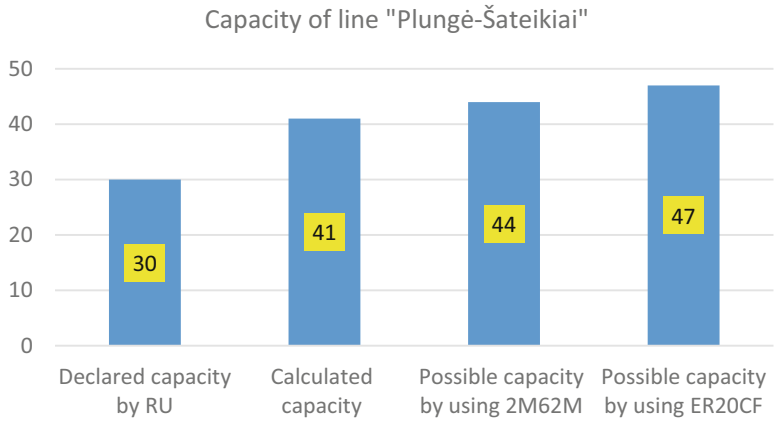

Fig. 5. The capacity of the line "Plungė – Šateikiai" in pairs of trains.

It can be state that Lithuanian RU does not rationally uses the public railway infrastructure, and the chosen method of compiling the service train schedule does not ensure the maximum possible capacity of lines.

3.4 Capacity of Single-Track Line "Livintai – Gaižiūnai"

The limiting single-track line "Livintai – Gaižiūnai" is located on the railway section "Kaišiadorys – Radviliškis". It is equipped with an automatic blocking. "Livintai – Gaižiūnai" line is 11.9 km long. Both stations bordering the line are equipped with microprocessor centralization of switchers and signals. The speed limit for freight trains is 90 km/h. Freight trains in both directions pass through this station at an average speed of 65 km/h. The maximum capacity of the line "Livintai – Gaižiūnai" was calculated according to Formula (2). In order to more efficiently use the automatic blocking at the line, it is necessary to set trains, i.e., allow one-way trains one after the other "in group". Assuming the condition that the number of trains in the set will be two trains, it was gained a theoretical capacity $N = 52$ pairs of trains. Figure 6 shows the capacity diagram for this line "Livintai – Gaižiūnai".

Thus, the method of compiling the official train schedule chosen by the Lithuanian RU for organizing the running of freight trains in problematic (single-track) lines does not ensure the maximum possible capacity.

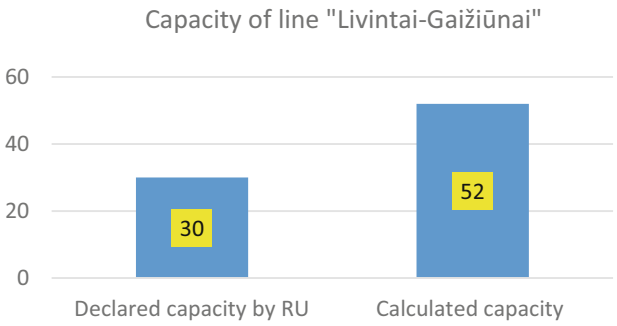

Fig. 6. The capacity of the line "Livintai – Gaižiūnai" in pairs of trains.

4 Conclusions

Insufficient capacity of the public railway infrastructure restricts the competition of the railway transport market and disturbs the liberalization of the activity of the whole transport sector of Lithuania. Incorrect determination of the maximum possible capacity of railway lines does not ensure rational and efficient use of the public infrastructure potential of Lithuanian Railways. The capacity of the railway line "Viduklė–Tauragė" declared and actually implemented by the Lithuanian railway undertaking is 1.5 times lower than the revised capacity, of the line "Plungė –Šateikiai" – 1.6 times and of the line "Livintai – Gaižiūnai" – 1.7 times.

In order to increase the capacity of railway lines with automatic blocking, the arrangers of train traffic by packaging method is applicable. In Lithuanian Railways, the traffic schedule of non-pair trains is not still sufficient applied for increasing the capacity of problematic lines.

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