MIRKO ČIČAK, D.Sc.
Institut prometa i veza
Zagreb, Kušlanova 2, Republika Hrvatska
DRAGAN BADANJAK, D.Sc.
Fakultet prometnih znanosti
Zagreb, Vukelićeva 4, Republika Hrvatska
JOSIP KUKEC, D.Sc.
Hrvatske željeznice
Zagreb, Mihanovićeva 12, Republika Hrvatska

Traffic Safety
Preliminary Communication
U. D. C.: 656.2:656.02
Accepted: Jan. 5, 2001
Approved: Dec. 12, 2001

THE CAPACITY OF CONFLICT POINTS BETWEEN DOUBLE-TRACK LINES

ABSTRACT

The objective of the railway is to offer high level of transport services, i.e. the quality which is competitive to other transport modes, but which minimises its internal costs at the same time.

In order to increase the capacity of transport services and reduce the costs, splitting of trains between different categories of transport on separate railway lines will be more and more applied in the 21st century. Unfortunately, even in the developed countries there will be lines or line sections where mixed traffic will be carried, and in developing countries this will often be the case even on the main trunk lines.

Therefore, a topical issue is to establish the capacity and choose the right solution. The problem becomes more complex in cases when two double-track lines with mixed traffic need to be connected and the restructuring of traffic implemented. At the same time the exits to two new double-track lines with the specific train categories have to be ensured and the required quality of transport services maintained.

In this paper, the impact the capacity has on quality is discussed and some basic characteristics of a model, which enables the research of the conflict points capacity, i.e. of converging and diverging points of two double-track lines is given. Although, there are some analytical elements in this model, it is essentially simulation which enables us to carry out tests under different conditions, to study different variants and to systematise different indicators and make conclusions.

KEY WORDS

conflict points, double-track lines, capacity, crossing of lines

1. INTRODUCTION

The objective of the railway is to supply high quality transport services required by the customers, i.e. the quality competitive to other transport modes, providing that at the same time it does not minimize the costs which include investment and operating costs.

In order to achieve this objective, different variants are investigated already in the planning phase so as to arrive at the best solution possible. In doing this, particular importance is focused on the evaluation of variants and criteria for this evaluation. In addition to the economic criteria through which benefits and costs can be expressed, city-planning/spatial, environmental, safety and other criteria should also be considered, and sometimes it is not so simple to express these through direct costs and benefits. A particular problem in these investigations is the capacity and its impact on the quality of transport services.

It is for the purpose of increasing the quality of transport services and of reducing the costs that in the 21st century the trend of splitting different categories of traffic on railway lines will be continued more and more notably. On routes with high-intensity passenger flows and in the countries with higher financial viability, this process will develop much faster.

Unfortunately, even in the developed countries there will be some lines or sections of lines where the mixed traffic will still remain, i.e. the traffic of different train categories, and especially in the developing countries, very often even on the main trunk lines. A topical issue of today and of the future, therefore, is the one of establishing the capacity and choosing the solution under such conditions. This problem becomes particularly complicated when two double--track lines with mixed traffic are to be converged, followed by the traffic restructuring, i.e. ensuring the exit onto two new double-track lines, but with required train categories, maintaining at the same time a satisfactory level of the transport services.

This paper sets out the basic features of the model, which enables the investigations of the conflicting points capacity, i.e. the points of converging and diverging of double-track lines, as well as the impact of the capacity on quality. Although the model incorporates analytical elements, it is basically a simulation model and it enables the experimenting under different conditions, research into different variants, systemization of different indicators and making of conclusions.

2. PROBLEM SETTING AND SOLVING METHODS

In places of converging and diverging of lines, i.e. in places where need arises for trains to pass from one line to another, conflict points arise which can be settled in different ways. The problem of conflicting, apart from the crossing of the routes becomes even more complex with an increasing level of traffic mixing, because in addition to crossing of the routes, one must also consider the points of overtaking.

Let us assume two double-track lines from A and B. At their converging, it must be made possible for the trains to continue their movement from each of them to C or D, or vice versa, from C and D to A or B (Fig. 1). In this case, obviously, eight points occur where routes intersect, as well as eight points where routes converge and diverge, respectively. The intersecting points can be resolved in different ways, but this will be enabled also by different capacity, which, as a rule, is limiting and will, therefore, represent a bottleneck not only for the point where the lines converge or diverge, but also for the adjacent line sections.

At the same time, different solutions will require different investments, and even the operating costs may vary to some extent. Characteristic solutions of these conflicting points are shown in Fig. 2 (under a, b and c).

With different solutions of the conflicting points, question arises of the level of capacity and whether such capacity restricts the capacity of the neighbouring sections and if so, to what extent? Another question is, which solution to choose? The capacity of these conflicting points can be roughly established by analytical methods, or in more detail, by means of simulation models.

As analytical model the UIC, DB and other methods are used. Some railways, and among them Russian railways in particular, in establishing the capacity of double-track sections, establish first the theoretical capacity, and then the remaining capacity for freight trains (direct and sectional trains which have approximately the same weights and speeds), after covering the necessary part of capacities for train categories the speeds of which are significantly different (passenger, accelerated freight, pick-up trains). Both approaches incorporate elements the values of which cannot be established accurately in exact analytical terms, but they are established only approximately through investigations based on approximate analytical terms of mass servicing or on simulation models.

So far as the points of converging and diverging of two double-track lines are concerned, the establishing of line capacity becomes more complicated because in changing from one track to the other at the same crossing level, on a short line stretch, a significant growth in the number of trains and notable non-homogenization on line sections take place, and on the other hand, it is much more complicated to determine a mean value of the minimum interval relevant for the capacity calculation, as well as the recovery time. It is, therefore, advisable to form special simulation models for such conditions.

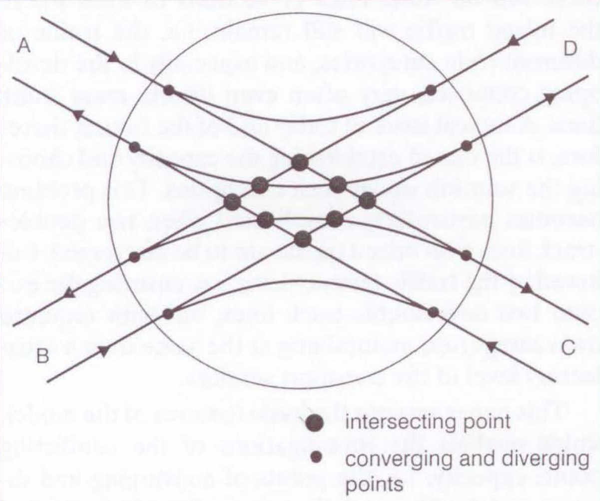

Figure 1 - Conflicting points in converging and diverging of two double-track lines

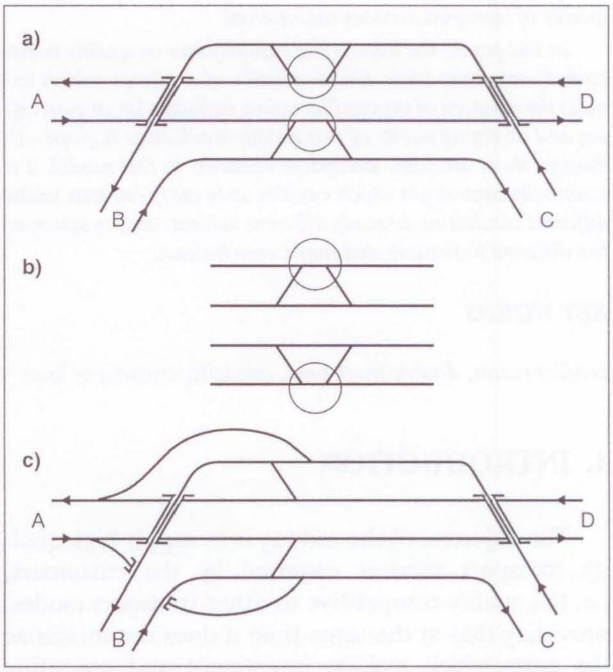

Figure 2 - Basic technical solutions of the problem

3. THE BASIC ELEMENTS OF THE MODEL FOR ESTABLISHING THE CONFLICTING POINTS CAPACITY

When investigating the converging and diverging of two double-track lines, due to the mixed traffic, it is also necessary, in addition to train restructuring, to consider the overtaking points due. The model, also has to include, besides the solution for converging and diverging of two double-track lines, the minimum of at least one station for overtaking at each section (Fig. 3).

The model includes:

- line sections with basic characteristics and with overtaking stations, as well as the assumed solution for converging and diverging, respectively, of two double-track lines;
- train categories with essential characteristics;
- the assigned manner of trains appearance (generation) in the model, i.e. before the overtaking stations at braking distance of high-speed trains, which may be either determinant, i.e. according to the given time-table, or random, accidental?

The basic characteristic of the proposed model is that it is set dynamically, i.e. the train movement, train movement control and monitoring are all performed by imitating a real-time process. After trains "enter" the system, move through it, a decision on their movement, stopping and route is made in relation to a concrete traffic situation, i.e. in relation to the situation and categories of trains which either are in the system, or will enter it in the near future, in compliance with the defined conditions and principles related to the train movement control applicable in the real system. Thus the train has assumed all attributes of an "expert system" of train movement and movement control along the line sections under consideration.

A separate part of the model deals with solving of the problem of train overtaking, which happens due to the existence of a number of train categories with notable differences in their movement speed. The basic idea applied in solving this problem is in that the trains at particular points of time (in a particular position on the route of moving through the system) obtain information on trains which are in the system behind them, or are expected to enter the system - train category, location on the route in a certain period of time Δt. After that, the expected moments of train arrivals to check points (overtaking stations) are determined in relation to a consecutive train, if it is of a higher rank. If the difference of expected moments of train arrivals to the next station does not satisfy the values of station intervals, the train overtaking must be envisaged at the preceding check point, i.e. station. Then the following elements are established for the train to be overtaken: place of overtaking, route, overtaking time and the moment when it is included back into the movement process (after a higher ranking train which does the overtaking has passed the check point under consideration).

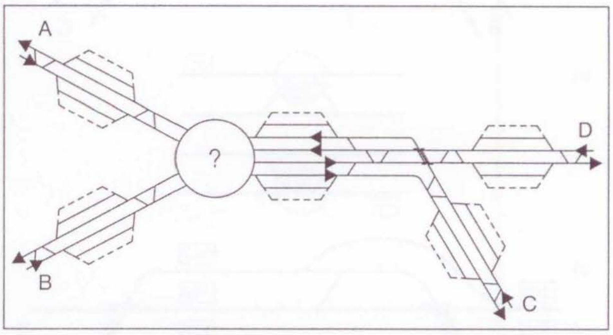

Figure 3 - The minimum coverage of the simulation model

The model enables the monitoring of trains separately and by category, as well as the monitoring of route elements.

Trains with speeds of up to 160 km/h are assumed to move within the classical signalling system, whereas trains exceeding speeds of 160 km/h move within the system of automatic train control, i.e. at the braking distance, viz. the minimum sequencing interval.

4. OUTPUT RESULTS

For the assumed structure (categories) of trains and their numbers as well as the different ways of restructuring in passing from one line to the other, different capacity solutions are obtained. A characteristic example is given in Figure 4 where for a good quality of transport service ($\rho \approx 0,5$) the capacity of conflict points is limited to 96 and 97 trains per day respectively (Fig. 4a), and for other solution to 87 and 98 trains per day respectively, (Fig. 4b).

It should, however, be considered that the capacity of each conflict point significantly decreases the capacity of the inbound line section. The capacity of the solution shown in Figure 4c with the assumed trains restructuring on converging of two double-track lines does not represent a bottleneck and does not limit the capacity of inbound sections.

Another characteristic found during these investigations is that the capacity of conflicting points with solutions involving the at-grade crossing, for the purpose of achieving the required quality, decreases down to 30%, in relation to the track loading, numbers of trains passing from one track to another and differences in "sources" (lines) of trains that appear on the joint track.

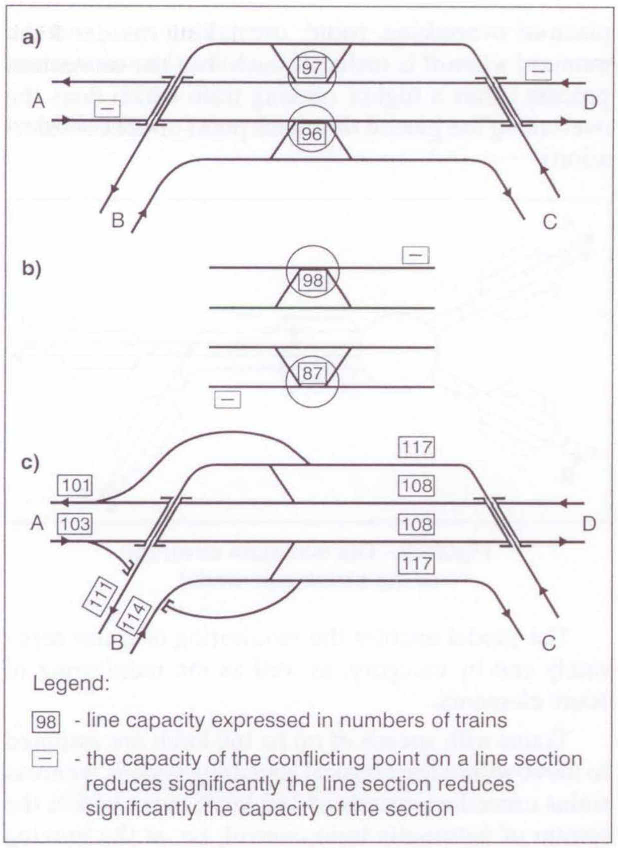

Figure 4 - The capacity of conflict points and of line sections respectively

5. CONCLUSION

Based on the investigations which have partly been presented in the paper, the following conclusions can be made:

On converging and diverging of two double-track lines with mixed traffic and trains restructuring, the capacity of such points can be established in a simplified way in analytical terms, based on the theory of mass servicing, or empirical terms, or in more detail based on development of simulation models. If the solutions are offered partly with at-grade crossing, such places then become bottlenecks and significantly decrease the inbound sections capacity.

In order to provide adequate quality a significant reserve in capacity must exist also for the line sections which do not converge with other lines. The quality is assumed to be very good if the time utilization ranges from 0.3 up to 0.5, good from 0.5 to 0.6, rather bad from 0.6 to 0.7, and very bad over 0.7.

However, at converging points of two tracks belonging to different lines, the capacity decreases even down to 30%, in relation to the preceding one, depending on the loading of the joint section of the track, number of trains passing from one track to the other, structure of trains and other factors.

The capacity of conflict points on converging of double-track lines, partly at the same level, can be satisfactory with lower traffic volume, i.e. in the initial stages of development.

1. If on converging of double-track lines the technical solutions provide for all crossings of routes to be in two levels, the simulations then indicate that the capacity with such a solution with mixed traffic and significant trains restructuring, is not a bottleneck and does not limit the capacity of inbound line sections.
2. In order to select a solution it is not enough only to establish the capacity of converging and diverging points of two double-track lines for good quality of transport service, but it is also necessary to make a cost-benefit analysis, and if necessary, also the multiple-criteria analysis.

SAŽETAK

KAPACITET KONFLIKTNIH TOČAKA PRI SPAJANJU DVOKOLOSJEČNIH ŽELJEZNIČKIH PRUGA

Cilj željeznice je pružiti visoku kvalitetu prijevozne usluge, odnosno kvalitetu konkurentnu drugim vidovima prometa, a da pri tome minimalizira troškove. U cilju povećanja kapaciteta prijevozne usluge, a smanjenja troškova, u 21. stoljeću sve će više biti zastupljena tendencija razdvajanja različitih kategorija prometa na željezničkim prugama. Nažalost i kod razvijenih zemalja i u 21. stoljeću bit će pruga ili dijelova pruga na kojima će se zadržati mješoviti promet, tj. promet različitih kategorija vlakova, a posebno kod zemalja u razvoju pa čak često i na magistralnim prugama.

Zato je aktualno pitanje utvrđivanja kapaciteta i izbora rješenja u tim uvjetima. Taj problem postaje posebno kompliciran kada treba spojiti dvije dvokolosječne pruge s mješovitim prometom i izvršiti prestrukturiranje prometa, tj. omogućiti izlaz na nove dvije dvokolosječne pruge sa željenim kategorijama vlakova, a da se pri tome zadrži zadovoljavajuća kvaliteta prijevozne usluge. U ovom se radu daju osnovi modela koji omogućuje istraživanje kapaciteta konfliktnih točaka, tj. točaka gdje se spajaju i razdvajaju dvokolosječne pruge, kao i utjecaj kapaciteta na kvalitetu. Iako model ima analitičkih elemenata, on je u osnovi simulacijski i omogućuje eksperimentiranje u različitim uvjetima, istraživanje različitih varijanti, sistematizaciju različitih pokazatelja i donošenje zaključaka.

LITERATURE

[1] **Čičak M., Jokić M.**: "*Mathematical methods in railway traffic and transport*", Zavod za novinsko-izdavačku delatnost, Beograd 1987

[2] **Čičak M.**: "*Railway traffic organization*", Faculty of Transport and Traffic Engineering, University of Belgrade, Belgrade, 1990.

[3] DB: "Programmfamilie SLS", Verkehrswissenschaftliches Institut RWTH, Aachen, 1990

[4] **Gruntov P. S.**: "*Upravlenie ekspluatacionnoj rabotoj i kačestvom perevozok na železnodorožnom transporte*", Transport, Moskva, 1994

[5] **Schwanhäuβer W.**: "Leistungsfähigkeit und Bemessung von Bahnanlagen" Heft 41, Veröffentlichungen des Verkehrswissenschaftlichen Institutes der Rheinisch - Westfälishen Technischen Hochschule Aachen, 1987.

[6] UIC: "Methode zur Ermittlung der Leistungsfähigkeit von Strecken", 405-1, 1979.