

Jerzy PAWLICKI

THE EFFECT OF TECHNICAL AND OPERATING CHARACTERISTICS IN A SELECTED SIDING RAIL JUNCTION ON AN EXPECTED TRAFFIC SMOOTHNESS

Summary. The paper presents the results of the studies on effective use of a real track junction located at a confluence of three mine sidings and a railway-line track that interconnects a mine with district PKP station for different track structure of the junction and four speed variables for selected track sections, protections of neighbouring railway lines and junctions. Furthermore, the paper discusses the rules of traffic organization in a junction. For analysis, a simulation model of track junction with adjacent railway-line tracks (a model of branched junction with surroundings) was applied.

WPLYW PARAMETRÓW STRUKTURY TECHNICZNO-RUCHOWEJ W WYBRANYM BOCZNIKOWYM WĘZLE TOROWYM NA WARTOŚĆ OCZEKIWANEJ PŁYNNOŚCI RUCHU

Streszczenie. W artykule przedstawiono wyniki badań efektywności wykorzystania rzeczywistego węzła torowego, powstałego u zbiegu trzech kopalnianych linii bocznicowych oraz linii kolejowej łączącej punkty załadunku węgla ze stacją zbiorczą PKP dla różnych struktur torowych węzła przy czterech parametrach zmiennych : prędkości na wybranych odcinkach torów, sposobie zabezpieczenia węzła i jego otoczenia oraz regułach organizacji ruchu w węźle.

1. Introduction

The railway transportation system in the province of Katowice up to 1990 can be briefly characterized as follows :

- 90% cargo shipped from the province comprised the products of mining and metallurgical industries, wherein about 80% constituted coal transport,
- a system of siding tracks is excessively developed in addition to a dense system of PKP tracks,

- a great part of mine tracks is located on the areas subject to subsidence. The latter has caused and still causes limitations in a speed of trains, an increased failure rate of traffic control equipment, damages in a track structure and subgrade etc..

The factors mentioned above were a source of congestions in most parts of railway and siding systems and shunting yards resulting in frequent disturbances of railway traffic whose elimination required continuous adjustments in unpredictable moments.

Recently, new circumstances considerably effecting the structure, scope and quality of railway transport have appeared in the province. The most important factors include:

- a reduction of coal mining by about 30%, closure of some mines or reduction of their production,
- a reduced quantity of transported stowing materials replaced with stone recovered from a coal cleaning at place,
- a presence of new private carriers by land who successfully compete with State Railway (PKP) in a field of mining transport services.

From a viewpoint of mine siding owner, some ease in transportation is advantageous for PKP. The irregularity in delivery of the cars of a specific type, in a required number and at a proper date, is reduced. Therefore, it is not longer necessary to gather a rolling stock in excessive number at a siding. Also, the trains are sent to the system more regularly.

The above remarks make it possible to state that the present system of siding tracks is insufficiently used due to declining transportation tasks. The track sections are occasionally not in operation for technical reasons, but a question arises whether it is reasonable to operate the expensive and worn siding infrastructure in its current size.

A permanent elimination of some sections in siding system from normal operation, dictated by economic or technical reasons, results in a greater traffic on the remaining tracks, where as improved traffic conditions in the PKP system of high capacity allow to increase a smoothness of moving the trains along mine tracks.

In railway junctions, a new traffic organization - a new balance system, adapted to the changing technical and operational conditions, is created. It solves the traffic capacity problems in the PKP system. One of the most important factors effecting the traffic capacity of the track

junctions, where the largest limitations take place, is a station arrangement. The latter is dependent on a technical infrastructure of the surroundings.

The paper presents the results of the studies on effective use of a real track junction located at a confluence of three mine sidings and a railway-line track that interconnects a mine with district PKP station (Fig. 3) for different track structure of the junction and four speed variables for selected track sections, protections of neighbouring railway lines and junctions. Furthermore, the paper discusses the rules of traffic organization in a junction.

2. Technical and operational description of a junction model

For analysis, a simulation model of track junction with adjacent railway-line tracks (a model of branched junction with surroundings) was applied. The model is based on mw46 and m416 prepared by J.Woch. Computations were carried out basing on SOUT microcomputer software of a new generation for IBM PC/AT computer. A criterion of maximum traffic smoothness [2] was adopted as basic for evaluation of the effectiveness of the junction use.

A measure of traffic quality is defined by probability:

$$f(d, r) = 1 - p(d, r) \quad (1)$$

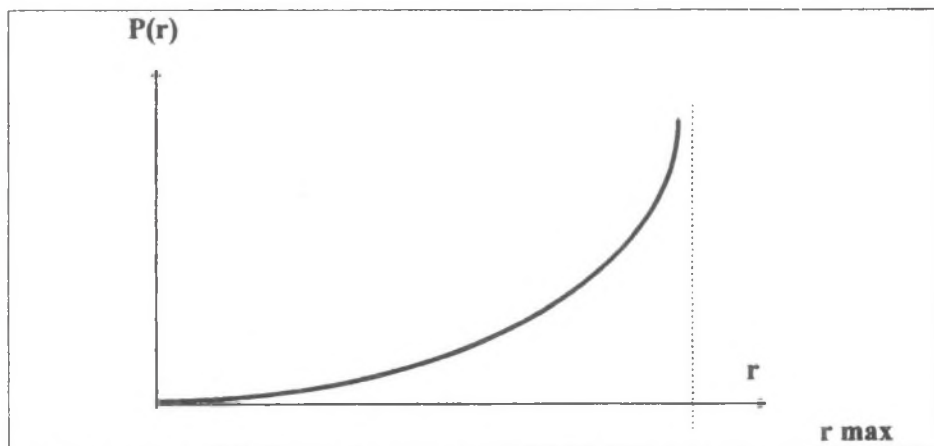


Fig. 1. A relationship of the traffic delay probability $P(r)$ vs. the traffic intensity at the track junction

Rys. 1. Zależność prawdopodobieństwa opóźnienia potoku ruchu $P(r)$ od intensywności ruchu dla rejonu węzła torowego. Source: [2]

It is defined as a probability of traffic smoothness (Fig. 1). A loss in quality of a system operation is measured by probability $p(d,r)$ that a smooth motion of the unit announced to the system (d,r) is to be disturbed by motion of the earlier unit. In the above equation, d and r refer to line structure parameters and traffic, respectively.

The relative measure of traffic smoothness is defined as an expected number of units which travel smoothly through the examined cross-section of the system at a predetermined time interval. If r is specifically defined as an intensity of announcements to the system, a traffic smoothness can be described as follows :

$$F(d, r) = (1 - p(d, r)) r \quad (2)$$

It is the fundamental characteristics of the effective use of the system. At a steady track structure, $F(r) = F(d,r)$ is a criterion function. The latter allows to determine an optimum number of announcements (optimum traffic capacity) in terms of the highest traffic smoothness ie. r_0 value for which $F(r_0) = \max$ (Fig. 2).

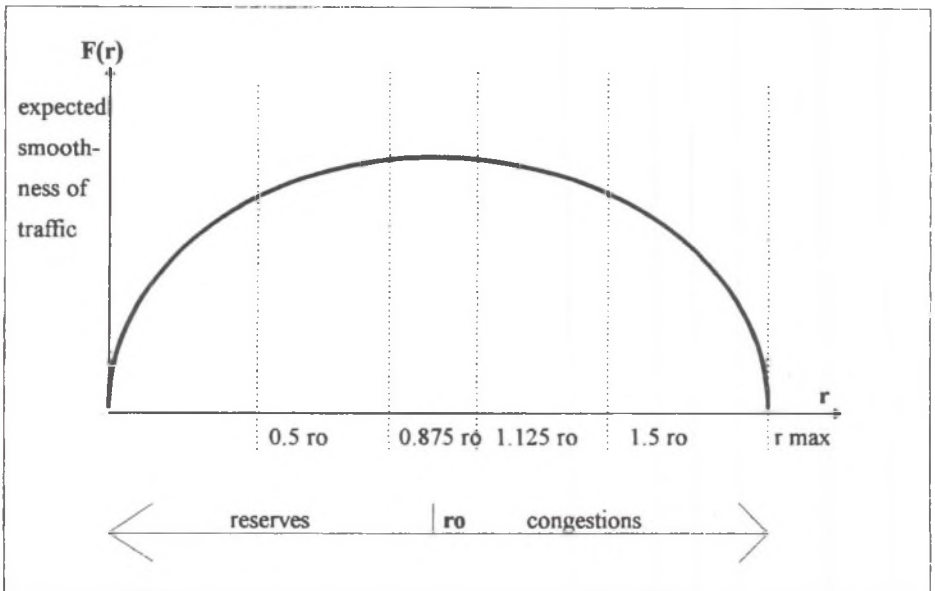


Fig.2. A relationship of the expected traffic smoothness $F(r)$ vs. the traffic intensity

Rys.2. Zależność oczekiwanej płynności ruchu $F(r)$ od intensywności ruchu

Source: [2]

In practice, one may assume that the nearest surroundings of optimum traffic intensity ($0.875 r_o$, $1.125 r_o$) is the interval of the optimum capacity. When $R < 0.5 r_o$, there are very large reserves in use of optimum capacity. If $R > 1.5 r_o$, extremely serious congestions take place. Optimum traffic intensity in terms of smoothness shall be considered as a "pessimistic" evaluation of practical traffic capacity of the system.

Operation of three systems in the junction was analyzed in two program modes. In the first traffic mode, a course of the trains was simulated at unchanged traffic streams to carry out a preliminary analysis of collision probability. In the second mode, optimum traffic intensity was determined assuming the proportional variability of all the categories of trains.

Practically, all the streams do not increase in proportion, but reliable results can be easily obtained.

Fig. 3 (Scheme I) shows a technical and operational description of the existing system with basic assumptions as follows: the lengths of track distances in the examined junction are constant ie. 2800, 2800, 3100, 3100, 4000 and 1500 m, respectively. During tests, the assumed speeds and train announcement classifiers on 3rd and 4th tracks do not undergo any change. The same concerns a number of trains in particular streams (see Table 1).

Table 1

Description of train categories

Categories No.	Description of trains	Assumed a number of trains per day
1	trains with coal from a mine 1 to a district station 2	12
2	trains of a mining company from a mine 1 to a point 2	4
3	trains with empty coal cars from a source 2 to a point 1	12
4	trains of a mining company from a district station 2 to a mine 1	4
5	trains with empty coal cars from a source to a point 3	9
6	trains with empty coal cars from a district station 2 to a point 4	4
7	trains from a mine 2 to a district station 2	9
8	trains from a mine 3 to a point 2	4

Source: Own report

The above assumptions relate also to the Schemes II and III. Table 2 presents the variability of speeds. Table 3 shows the variability of protections. In Table 4, the applied priorities of travels through the junction are given. In all simulations, two kinds of protections for the junction were taken into consideration ie. electromechanical and relay equipment.

The results of simulating the junction operation for extreme technical and operational conditions are presented in Table 5. Table 6 includes selected general parameters and characteristics at maximum and minimum variants of speeds and protections on the junction surroundings as specified in Table 5.

Table 2

Variants of the assumed speeds at adjacent line tracks [km/h]

Variant type	Track No.					
	1	2	3	4	5 ^{1),2)}	6 ¹⁾
a	40	40	25	15	40	40
b	25	40	25	15	25	40
c	25	25	25	15	25	25

Source: Own report

1) concerns tract structures I

2) non-concerns tract structures II

Table 3

Variants of the applied protections for adjacent siding tracks

Variant type	Track No.					
	1	2	3	4	5	6
α	2	2	1	1	2	2
β	1	2	1	1	1	2
γ	1	1	1	1	1	1

Source: Own report

1- telephone announcement

2-semi-automatic interlocking

Table 4

A configuration of the assumed weights of priorities for passing
the trains through junction

Arrange - ment type of priority weights	Train categories							
	from 1 to 2		from 2 to 1		from 2 to 3	from 2 to 4	from 3 to 2	from 4 to 2
	1	2	3	4	5	6	7	8
A	2	1.5	1	1.5	1	1	2	2
B	1	1.5	2	1.5	2	2	1	1
C	2	1.5	2	1.5	2	2	1	1
D	2	1.5	2	1.5	2	2	2	2
E	2	1.5	2	1.5	1	1	1	1
F	2	1.5	2	1.5	1	1	2	2
G	2	1.5	2	1.5	2	1	2	1
H	2	1.5	2	1.5	1	2	1	2
I	2	1.5	2	1.5	1	2	2	1
J	1	1.5	1	1.5	2	2	1	1

Source: Own report

3. Analysis of results and final conclusions

Optimum traffic capacity of the junction in terms of traffic smoothness is determined, for evident reasons, by a track structure of the post (at a determined length of track distances). For Scheme III (all one-track lines), the very long inconsistency occurs. It effects considerably the average times of trains sequence. For example, maximum optimum traffic capacities of the junction for systems I and III differ by 92 units at the same configuration of the remaining parameters, while a difference between maximum and minimum values in I and III Schemes,

respectively, is 172 trains. However, it should be stated that the junction arrangement with two-way traffic can serve that existing streams with low congestions that take place at the most disadvantageous traffic conditions.

Table 5

A list of simulation results. Optimum traffic intensities for most advantageous and disadvantageous technical and operating conditions

General characte- ristics	Variants of the assumed variable parameters					
	Track structure I		Track structure II		Track structure III	
	max	min.	max	min.	max	min.
	C, a, α	F, c, γ	B, a, α	F, c, γ	C, a, α	D, c, γ
optimum traffic intensities (ro)	222	114	178	78	130	50
expected traffic smoothness F(r)	134.5	75.4	91.9	50.9	66.6	32.3
average time of stops x [min]	16.8	4.1	10.2	4.1	33.3	6.6

Source: Own report

Table 6

A differentiation of optimum traffic capacities at extreme speed variants and protections of line tracks as shown in Table 5

General characteristics	Track structure I				Track structure II				Track structure III			
	a, α		c, γ		a, α		c, γ		a, α		c, γ	
	max	min.	max	min.	max	min.	max	min.	max	min.	max	min.
	C	F	B	F	B	F	B	F	C	D	B	D
optimum traffic intensities (ro)	222	190	148	114	178	148	106	78	130	78	78	50
expected traffic smoothness F(r)	134.5	94	82.4	75.4	91.9	73.5	61.9	50.9	66.6	47.5	41	32.3
average time of stops x [min]	16.8	7	8.8	4.1	10.2	6.4	9.8	4.1	33.3	4.1	33.6	6.6

Source: Own report

The second factor greatly increasing the optimum traffic capacity was a speed, the increase of which from 25 km/h to 40 km/h resulted in the increments of the traffic capacity by 95%, 128% and 160% in the systems I, II, III, accordingly. Such results could be expected, but the increments of the traffic capacity were unexpectedly high.

The third factor significantly changing the traffic conditions at a junction concerned the rules of trains travel ie. a proper selection of priorities (see Fig. 4).

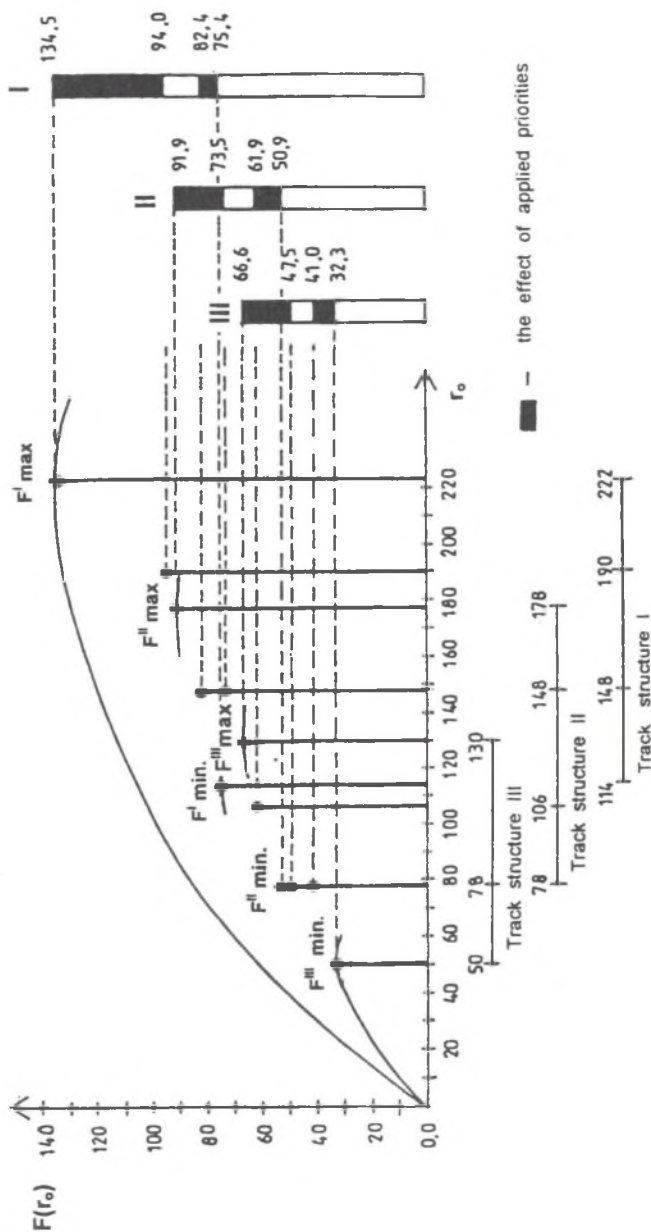


Fig. 4. The effect of weight system of the priorities on an expected smoothness of traffic
Rys. 4. Wpływ układu wag priorytetów na wartość oczekiwanej płynności ruchu
Source: Table 6

The correctly selected weight system of the priorities can balance the advantages gained from increasing the speed and application of better equipment. For example, a maximum traffic capacity of the junction for Scheme III at 25 km/h, telephone announcement in the sources 1 and 2 and electromechanical equipment at a switching station, is equal to a minimum traffic capacity achieved for a speed of 40 km/h, when the semi-automatic interlocking system and relay equipment are installed ie. 78 trains per day. The combinations B and C constitute the most convenient weight systems of the priorities. They predict a right of way for frequented streams (crossing collision) from the source 2 to 3. The lowest optimum intensity was achieved in a case D (all priorities are equal, except the travels of mine trains) and F. In the latter case, the stream from 2 to 3 is also of decisive importance. Furthermore, it was found that:

- optimum traffic capacity of the system III for a speed "c" is lower than the assumed traffic intensity (58 trains), except the weights of the priorities B (78 trains), C(70) and J(66),
- a replacement of the "a, α " by "a, β " system ie. a use of telephone announcement for the track 1 reduces the traffic capacity of the junction from 130 to 108 trains per day for C priority but it remains unchanged for A priority,
- a replacement of the "a, β " system by "b, β " system, where the traffic capacity of the junction limits a speed in the track 1, deteriorates further the operating conditions of the junction. The traffic capacity for A priority is reduced to 98 trains per day and remains unchanged for C priority (108),
- a further reduction in traffic capacity is observed at the "c, β " system, where optimum traffic intensities approach the assumed ones,
- the systems of three factors "c, γ , D" is the least advantageous as it can be seen in Table 6,
- the use of electromechanical or relay equipment does not significantly influence the traffic capacity of the junction.

The analysis confirmed our assumption that this apparently simple track arrangement is more complicated and in practice its traffic capacity needs to be analyzed separately. The modelling problems are so complicated here that computer simulation is necessary for their solution.

References

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Streszczenie

W celu zbadania wpływu czterech parametrów - wymienionych we wstępie - na efektywność wykorzystania węzła torowego posłużono się modelem symulacyjnym opracowanym przez J. Wocha. Wprowadzone w modelu pojęcie optymalnej intensywności ruchu r_0 takiej, że oczekiwana liczba jednostek ruchu obsługiwanych płynnie (wzór 2) osiąga wartość największą, posłużyło za kryterium określania tzw. projektowej przepustowości praktycznej przy założeniu minimalnej równomierności ruchu.

Badanie przeprowadzono dla trzech struktur torowych węzła, stałych długości odstępów szlakowych oraz rzeczywistych kategorii jednostek ruchu (tablica 1) zmieniając prędkości na wybranych torach, typ urządzeń zabezpieczenia węzła i odstępów szlakowych, stosując zarazem wariantowanie porządku przepuszczania jednostek przez układ.

Wiadomo a priori, w jaki sposób optymalną przepustowość węzła w sensie płynności ruchu określają: jego struktura torowa, długości odstępów oraz stosowane prędkości przejazdu jednostek przez węzeł. Precyzyjnie zależności te podano w modelu matematycznym [2].

W tablicach 5 i 6 przedstawiono maksymalne i minimalne wartości optymalnych intensywności ruchu, oczekiwanych płynności oraz strat czasu otrzymanych w wyniku zastosowania różnych kombinacji zadanych prędkości, urządzeń srk oraz wszystkich wariantów priorytetów dla możliwych przebiegów. Wyniki symulacji obrazują, że właściwie

dobrany układ wag priorytetów może zrównoważyć korzyści uzyskane ze zwiększenia prędkości i zastosowania lepszych eksploatacyjnie urządzeń srk.

Przedmiotem badań było określenie oczekiwanych płynności ruchu w warunkach minimalnej równomierności obciążenia układu. W artykule pominięto zagadnienie organizacyjnej przepustowości praktycznej, tzn. oczekiwanej liczby jednostek $r_1 > r_0$, których strata czasu w badanym węźle nie przekracza pewnej dopuszczalnej wartości. Powyższa problematyka stanowi przedmiot zainteresowań projektanta organizacji całej sieci kolejowej, a nie poszczególnych jej fragmentów.