# The Changeable Block Distance System Analysis

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**Abstract.** The paper treats about efficiency analysis in Changeable Block Distance (CBD) System connected with wireless positioning and control of train. The analysis is based on modeling of typical ERTMS line and comparison with actual and future traffic. The calculations are related to assumed parameters of railway traffic corresponding to real time – table of distance Psary – Góra Włodowska from CMK line equipped in classic, ETCS Level 1 and ETCS with CBD systems.

**Keywords:** ERTMS, Changeable Block System, moving block section, efficiency analysis.

## 1 Introduction

The idea of Changeable Block Distance (CBD) presented in the paper is based on the following assumptions;

- The analyzed line is based on the central railway line in Poland (CMK) equipped with four state block system and typical railway control devices assuring the 160 km/h speed. The proposed modernization assumes the ETCS Level 1 system (without GSM-R) used virtual block distance, where information about signaling states assuring the 200 km/h speed was transsmited by balises.
- The hypothetical line assumed for CBD calculations corresponds to CMK structure but with ETCS Level 2 (GSM-R), the balises placed in rails are used for zero of train odometer only and deck ETCS computer transmits the telegram about train position and speed via GSM-R to RBC centre (the precise position is calculated continuously as a distance from last balise).
- The passenger trains with maximal length 400 m (average 300 m) may travel with 160 km/h speed, the truck trains with maximal length 700 m (average 600 m) may travel with 120 km/h speed.
- With ETCS Level 1 the traditional, constant block distance is applied but with 200 km/h, the application of GSM-R and introduction of ETCS Level 2 allows

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to implement the CBD rule with 250 km/h speed. (For truck trains the CDB is restricted to the same 120 km/h speed).

- For analysis the absolute RDB model is assumed: the zero time for previous train stop after sending the last message about position (the constant protect way for breaking).

## 2 The Changeable Block Distance

The Fixed Block Distance (FDB) is a control method of proper sequence of trains is now based on positioning with respect to whole length between neighbor stations (so called one-distance block system) or with respect to block distance (so called multi-distance block system with assumed number of sections). Such method allows to localize the train in the one section of the block system (1300-1500m) according to the accessible speed of the train.

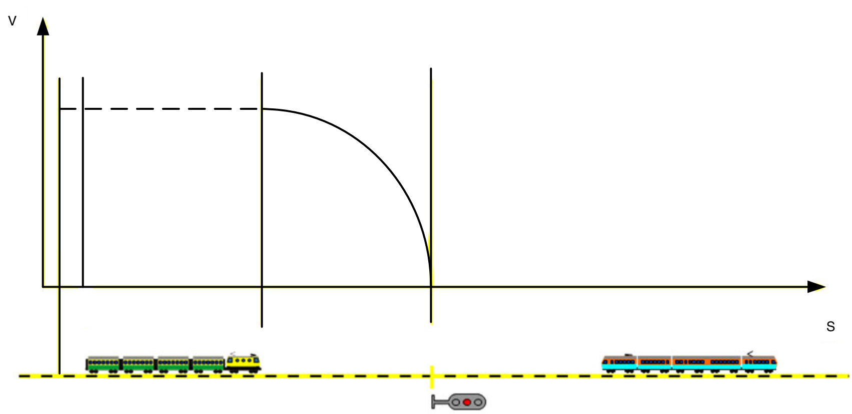


**Fig.1.** The rule of Fixed Block Distance (FDB)

This method assumes (in rough approach) division of the length between stations into given number of insulated sections related to required breaking way of the train. The occupation of the train the section after block signal transmits the message "occupied" (red light) to the this block signal and change information on a previous block signals, at the same informing the next train about number of not occupied sections and in consequence about permitted speed.

For ETCS level 1 (without GSM-R) the distance between neighbor balises may be similar to appropriate block sections because they must be placed near signals. It means that capacity of trains will be on the similar level (the increasing of speed from 160 km/h to 200km/h decreases the occupation time of rail section about 10%, but with assumption on mixed traffic with truck trains such value will be rather small).

The rule of the Changeable Block Distance (CDB) presented in the Fig.2 bases on the virtual block section with not fixed reference points (connected with distance between station) but flexible modified corresponding to given traffic situation. This method may be compared with "electronic visibility" when the actual speed depends on position and speed of a previous train. We can distinguish two variants of CDB:

- Fixed Changeable Block Distance (FCDB) when the second train receives the permission of drive to the place nearer than calculated on last report about position of a previous train. (It is connected with assumption about "zero distance" stop immediately after sending the report and total breaking way with protection way of second train.)
- Relative Changeable Block Distance (RCDB) when the second train receives the permission (movement authority) to the place nearer that the place whose may achieve end of a previous train after sending the last localization report. In such approach the distance between trains may be shorter than calculated breaking way of second train. In this method the very important is reaction time (delay in transmission of information about position of previous train end).

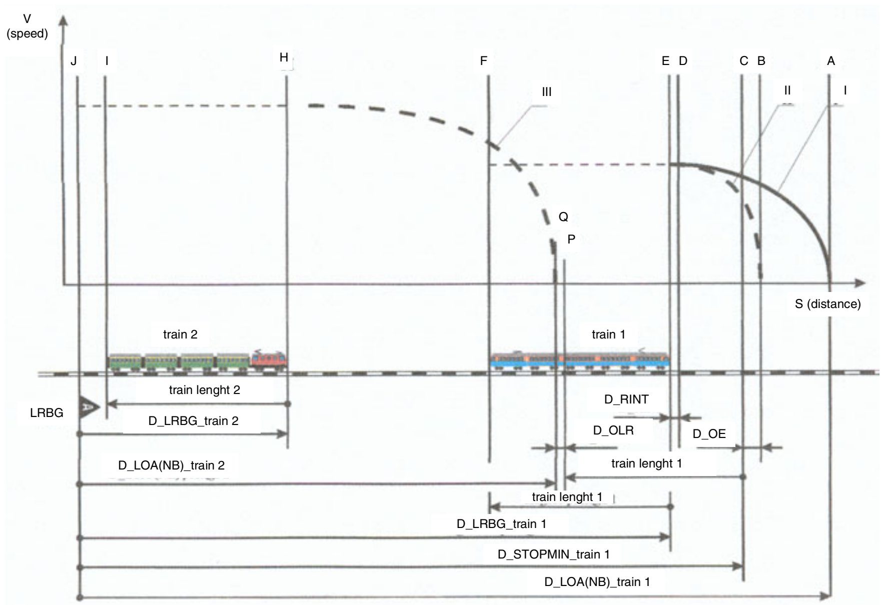


**Fig. 2.** The rule of Changeable Block Distance (CDB)

The distance control process is shown at the Fig. 2. According to this rule the "train 2" receives Movement Authority (MA) about precise position with respect to calculated localisation of "train 1". If the case of calculated distance between train 2 and 1 is shorter "train2" receive from Radio Block Centre new permission (MA) with limited speed and distance information. Finally when the driver outrun MA parameters train system automatically start – " service brake – emergency brake".

The introduced meanings and variables correspond to:

- MA – movement authority,
- LRBG – Latest Received Balise Group,
- I, II, III, - dynamic V profile, - breaking curves,
- A – end of movement authority for "*train 1*",
- B – calculated localization of stop point for "*train 1*",
- C – calculated safety point of stop for "*train 1*",
- D – theoretical localization of train 1 (situation when RBC indicated information – the last localization report of train 1 lost)
- E – latest localization of front "*train 1*" – according to LRBG information,
- F – latest localization of end of "*train 1*" – according to LRBG information,
- H – latest localization of front "*train 2*" – according to LRBG information,
- I – latest localization of end of "*train 2*" – according to LRBG information,
- J – localization of LRBG (balises group),
- Q,P – safety point for "*train 2*" (stop point).

In such application (with GSM-R) the minimal distance between Train_1 and Train_2 may be assumed as:

$$I = I_{h2} - I_{h1} + s \tag{1}$$

where:

I – minimal safe distance between trains equals to maximal breaking way (with additional safety margin)
$I_{n1}$ – breaking way of previous Train_ (with fixed distance equals to zero)
$I_{n2}$ – breaking way of next train
S – safety margin.

The cover of GSM-R for existing railway line requires the 99.9999% of availability for data transmission (in both full duplex channels). Such requirement assumes:

- The distance between base stations, (BTS) is 3-4 km (maximum 4 trains in 2 directions assigned to 1 BTS for CMK line).
- The radio control/monitoring centre (RBC) may service up to 40 trains.
- The time necessary for processing of information from balise and train odometer is 200 ms.
- The processing time of telegram in RBC is 200 ms.
- The time necessary for connection train a – RBC is 400 ms (3 correct telegrams each 400 ms required), the totals time is about 2 s.
- The time necessary for transmission of telegram train – balise is 200 ms.
- The report and transmission of information about position (each per several seconds) may be assumed as continuous, the deck computer calculates the position with respect to last reference/zero point. These calculations 200 ms plus connection/sending the telegram 2000ms gives the whole cycle of transmission about 3 s including additional delay and processing.

- The time and frequency of transmission the permission to the train depends only on the periods when the train traffic situation changes (according to actual permission of drive and required time of inspire.

## 3 The Object and Connected Characteristics

For the CMK as reference line we can assume the following characteristics of insulated sections: the shortest – 1200 m, the longest – 2400 m, the medium – 1500m. The detailed analysis of all block sections and connected signals suggests that in existing structure the required distances of breaking way for trains with 200 km/h may be rather difficult to achieve.

For partial analysis the typical distance between neighbor station (Psary – Góra Włodowska) is shown in the Fig. 3

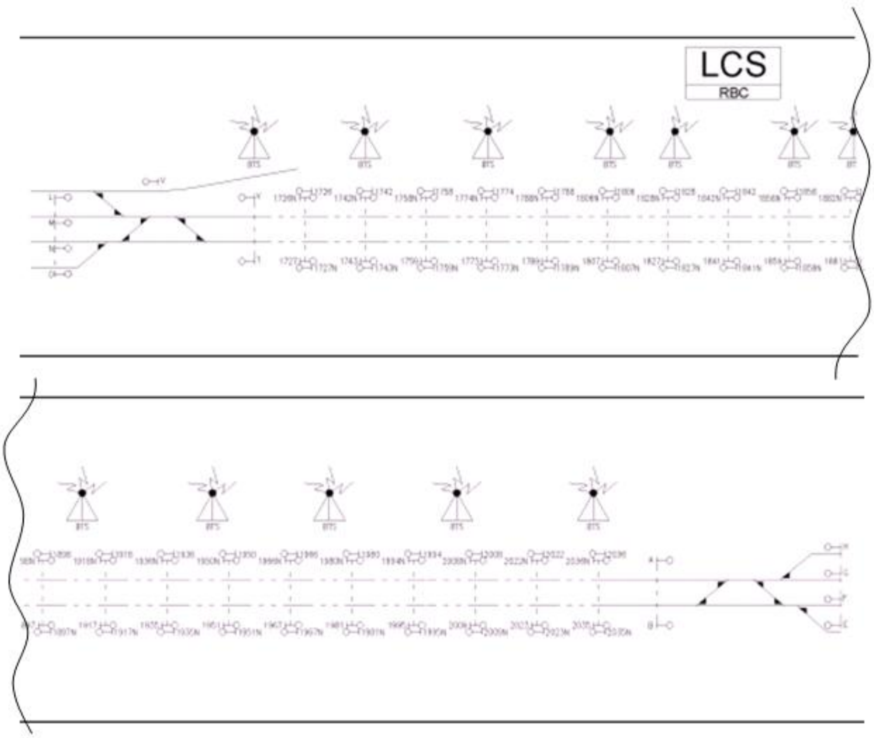


**Fig. 3.** The example of distance between two neighbor stations for CMK line

The detailed characteristics of traffic in the object from Fig. 3 is presented in the following table. This distance has length 34.715 km, identical for both directions of rails.

**Table 1.** The time table for object from Fig.3

| | Block no. | km | [m] | Block no. | km | [m] | Block no. | km | [m] | Block no. | km | [m] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | **Track 1** (Grodzisk-Zawiercie) | | | **Track 1** (Zawiercie-Grodzisk) | | | **Track 2** Grodzisk-Zawiercie) | | | **Track 2** (Zawiercie-Grodzisk) | | |
| Psary | B | 168630 | 1319 | F | 169378 | 1899 | A | 168630 | 1319 | G | 169406 | 1719 |
| *Track 3 / Track 4:* | **(6 Switch / *8 Switch*)** | | | *G* | *169406* | *1871* | **(7 Switch / *11 Switch*)** | | | *H* | *169547* | *1578* |
| *Track 3 / Track 4:* | *O* | *170256* | *1626* | **(6 Switch / *8 Switch*)** | | | *L* | *170220* | *1590* | **(7 Switch / *11 Switch*)** | | |
| | N | 170256 | 1626 | T | 171277 | 1426 | M | 170318 | 1688 | V | 171125 | 1581 |
| | 1727 | 172673 | 2417 | 1727N | 172703 | 1560 | 1726N | 172673 | 2355 | 1726 | 172706 | 1557 |
| | 1743 | 174233 | 1560 | 1743N | 174263 | 1597 | 1742N | 174233 | 1560 | 1742 | 174263 | 1597 |
| | 1759 | 175827 | 1594 | 1758N | 175860 | 1474 | 1758N | 175827 | 1594 | 1758 | 175860 | 1474 |
| | 1773 | 177304 | 1477 | 1773N | 177334 | 1548 | 1774N | 177304 | 1477 | 1774 | 177334 | 1548 |
| | 1789 | 178849 | 1545 | 1789N | 178882 | 1790 | 1788N | 178849 | 1545 | 1788 | 178882 | 1822 |
| | 1807 | 180672 | 1823 | 1807N | 180672 | 2119 | 1806N | 180672 | 1823 | 1806 | 180704 | 2087 |
| | 1827 | 182760 | 2088 | 1827N | 182791 | 1420 | 1828N | 182760 | 2088 | 1828 | 182791 | 1420 |
| | 1841 | 184180 | 1420 | 1841N | 184211 | 1645 | 1842N | 184180 | 1420 | 1842 | 184211 | 1645 |
| | 1859 | 185825 | 1645 | 1859N | 185856 | 2278 | 1858N | 185825 | 1645 | 1858 | 185856 | 2278 |
| (21 block) | 1881 | 188104 | 2279 | 1881N | 188134 | 1651 | 1882N | 188104 | 2279 | 1882 | 188134 | 1655 |
| | 1897 | 189754 | 1650 | 1897N | 189785 | 2022 | 1898N | 189754 | 1650 | 1898 | 189789 | 2018 |
| | 1917 | 191777 | 2023 | 1917N | 191807 | 1801 | 1918N | 191777 | 2023 | 1918 | 191807 | 1801 |
| | 1935 | 193578 | 1801 | 1935N | 193608 | 1451 | 1936N | 193578 | 1801 | 1936 | 193608 | 1451 |
| | 1951 | 195029 | 1451 | 1951N | 195059 | 1595 | 1950N | 195029 | 1451 | 1950 | 195059 | 1595 |
| | 1967 | 196632 | 1603 | 1967N | 196654 | 1470 | 1966N | 196632 | 1603 | 1966 | 196654 | 1470 |
| | 1981 | 198093 | 1461 | 1981N | 198124 | 1368 | 1980N | 198093 | 1461 | 1980 | 198124 | 1368 |
| | 1995 | 199462 | 1369 | 1995N | 199492 | 1405 | 1994N | 199462 | 1369 | 1994 | 199492 | 1405 |
| | 2009 | 200866 | 1404 | 2009N | 200897 | 1401 | 2008N | 200866 | 1404 | 2008 | 200897 | 1401 |
| | 2023 | 202266 | 1400 | 2023N | 202298 | 1311 | 2022N | 202166 | 1300 | 2022 | 202298 | 1311 |
| | 2035 | 203579 | 1313 | 2035N | 203609 | 2161 | 2036N | 203579 | 1413 | 2036 | 203609 | 2231 |
| Góra Włodowska | B | 204939 | 1360 | F | 205770 | 1464 | A | 204939 | 1360 | G | 205840 | 1394 |
| The minimal block: | | 1313 | m | | 1311 | m | | 1127 | M | | 1311 | m |
| The maximal block: | | 2417 | m | | 2278 | m | | 2355 | M | | 2278 | m |

# 4 The Capacity Evaluation

The capacity of railway line is exploitation parameter describing the maximal number of train pairs passing the railway line (or fragment) in assumed time (day or rush hour). It depends on following elements:

- Time-table speed
- Number of rails
- Length of rails and Block distances
- Composition of station rails
- Application of railway control devices
- Structure of traffic (type of trans)

From many different methods of capacity calculation the analytic method determines the element with minimal capacity (so called critical element). The time of occupation (or blocking with respect to UIC 406) of rails by two trains with sets of routes are similar in the traffic chart:

$$T = t_1 + t_b + t_2 + t_a \tag{2}$$

where:

$t_1,t_2$ – time of driving through rail (in both directions),

$t_a$, $t_b$ – time calculating in A and B stations.

The minimal capacity of rail section in pairs of trains per day may be expressed as:

$$N = (1-\varphi) * \frac{1440}{T} \tag{3}$$

where:

T – blocking time of section (traffic chart period)

φ – coefficient of traffic flexibility (always from period 0.2 – 0.3)

Assuming the parameters of FBD and existing control command systems (max speed 160 km/h) we can calculate medium time occupation block – 23 min and the capacity as 24 trains per day (maximal theoretical capacity as more 70 trains per day).

The maximal capacity ensuring by FBD method with ETCS L1 equipment for this object is connected with the following parameters: maximal speed 250 km/h and additional 5 HS trains per day. The calculated medium time of occupation block is 21 min and the capacity 29 trains per day (maximal theoretical capacity about 90 trains per day).

The application of CDB method (trains with 250 km/h and 4100 m distance - breaking way between trains 3500m plus train length 600m) allows to achieve the better parameters and in consequence the optimal value of occupation block (16 min) and capacity (29 trains similar to FDB and the maximal theoretical capacity about 100 trains per day). For traffic with HS trains only with 250 km/h theoretical maximal capacity may be 8 trains per hour or 200 trains per day.

## 5 Conclusions

It is obvious that virtual positioning of train according to GPS position may increase the capacity of trains. Assuming estimated value of capacity and assumptions on delays in transmitting message we can assure, that existing structure is sufficient for safe supervision of trains in CMK line, because the required number of trains assigned to BTS and RBC is satisfied.

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