The Number of Tracks in Main Track Groups

by Gerhart Potthoff, Prof., Dr-Eng.

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THE NUMBER OF TRACKS IN MAIN TRACK GROUPS

Prof Gerhart Potthoff
Doctor of Engineering
Dresden Technical College

1. THE PROBLEM

Main tracks, according to the Railway Construction and Operating Regulations, are those tracks used by trains in regular operation. Sometimes main tracks exist in groups, as for instance the entrance and exit tracks of a switching yard or the platform tracks of a passenger station, in which cases the tracks have similar or identical functions. In the first case (tracks with similar functions) each track has its own particular function: in a group of platform tracks, for instance, one track may be the through main track of the line AB in the direction AB and another track may be the overtaking track of the same line in the directions AB and BA, etc. If suitable switch connections are available, tracks within the group may substitute for each other. That is to say, a given track may fulfill not only its own particular function, but may also substitute for neighboring tracks, fulfilling functions normally belonging to them. In the second case (tracks with identical functions) the tracks are so arranged that any track may fulfill the functions pertaining to the group.

The way in which the tracks in an existing group are employed is shown graphically in a track utilization plan. In laying out new track facilities, the lowest feasible number of tracks is determined by the requirement that the track group be able to absorb without difficulty the scheduled peak traffic during the part of the day with the heaviest load. It is, however, also necessary to consider the possibility of time table changes, lateness of trains and other irregularities in operations (see item No 5 in bibliography). This makes it necessary to add a margin of safety to the minimum number of tracks determined under the track utilization plan. This margin of safety may be calculated with reference to the disturbances of traffic which may occur if the extra tracks are lacking. The question of the length of the daily period during which the peak load occurs deserves special consideration.

The method of determining the number of tracks will be illustrated by three examples. These are the entrance tracks of a switching yard (section 2), the freight train tracks of a medium sized ~~yard~~ station (section 3) and a group of passenger platform tracks (section 4).

2. ENTRANCE TRACKS OF A SWITCHING YARD

21. Processing Time

The utilization of an entry track is calculated as beginning with the point of time at which the dispatcher assigns the empty track [to an incoming train]. The time required for setting up the passage way for the train varies according to local conditions and may be determined by adding together the individual times values for the operation of signals, as set forth in a so-called (Block) "Signal Plan [redacted]" (items 8 and 10 in bibliography. The modal time for the set-

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ting up of the passage way is approximately two minutes. The next occurrence is the entrance of the train, which is reckoned from the moment when the trains passes a point the visual distance of 200 meters ahead of the advance entry signal until the train has stopped in the entrance track. In a particular case, for instance, the entrance path of the train consists of 200 meters (visual distance) + 700 meters (distance from advance entry signal to main entry signal) + 200 meters (distance from entry signal to beginning of first switch + 250 meters (switch zone) + 650 meters (length of train) = 2000 meters altogether. The time required for entrance including an allowance for braking should be about 4 minutes in this case but in practice is frequently longer.

After the train has stopped, the conductor turns over the manifests of the cars to the dispatcher. Rolling stock mechanics make a technical inspection of each car. The switching master or a special switching clerk prepares for the dispersion of the train by noting each car or group of cars on a switching order. Finally yard men unfasten the couplings and detach the air brake hoses between the cars or groups of cars to be separated and make the train ready for breaking up. The times required for these preparatory steps may take place simultaneously and if so which. The entire time for preparing to break up the train averages between 45 and 60 minutes (item 2 in bibliography). The actual breaking up is accomplished by having a switching locomotive move the train up to the hump, pushing the cars over it. This process is discussed in detail by Müller (items 10 and 11 in bibliography), who gives special consideration to the speed of the humping operation as affected by the height and gradient of the hump, wind and weather, type and loading of cars and number of cars handled as a unit for humping purposes. Not until the switching locomotive has left the entrance track after humping the train is the track available for the next train. The time elements from the assignment of the track by the dispatcher until the track again becomes free can be calculated for each operative step according to local conditions. The sum of these times we shall call the processing time, "b".

The train occupies the entrance track at least for the duration of the processing time.

22. Waiting Time

To the minimum time for occupancy of the track we must add the time during which no progress is made with operations, which we will designate as waiting time for "w". The sum of the processing time "b" and the waiting time "w" is the time during which the train occupies one of the tracks in the group.

221. The dispatcher cannot judge the time for setting up the passage way so accurately that the incoming train reaches the point at the visual distance ahead of the advance signal at the exact moment when this signal moves to "proceed". In order to avoid stopping the train on its way in, the dispatcher usually sets up the passage way a little earlier, the interval being named "margin of safety for entrance" by Behr (item 4 bibilography), who has determined that it averages about 13 seconds at a large passenger station.

222. Preparatory operations on the entrance track do not in all cases begin immediately after the entrance of the train, but are scheduled according to a work plan which keeps the various workers in the yard busy at all times. The waiting of trains for inspection after entry, for the writing of switching orders, etc, must be so regulated by the assignment of sufficient working forces that it remains within the waiting time hereinafter described and does not become of itself a factor determining the total load on the group of tracks.

223. The bottleneck in a switching yard is usually the hump. The operating speed in humping determines how fast the group of entrance tracks can be emptied. As soon as trains arrive faster than they can be humped, waiting time ensues.

2231. Diagram 1, based upon operating records in a switching yard, shows how the 13 trains arriving during a period of approximately six hours were humped. The average processing time in the yard is $b \approx 1.5$ hours. The time spent by the 13 trains on the entrance tracks varies between 1.5 and 2.5 hours, so that the waiting times vary between $w_{min} \approx 1.5 - 1.5 \approx 0$ and $w_{min} \approx 2.5 - 1.5 \approx 1.0$ hours. The median time spent by the trains on the tracks is 2.02 hours, so that the median waiting time is $w_m \approx 2.02 - 1.5 \approx 0.52$ hours. From the line connecting the times when humping operations of each train are completed we may read that every $c \approx 0.43$ hours a train is humped. From the line connecting the time of arrival we may see that frequently the trains arrive only $z \approx 0.2$ hours behind each other.

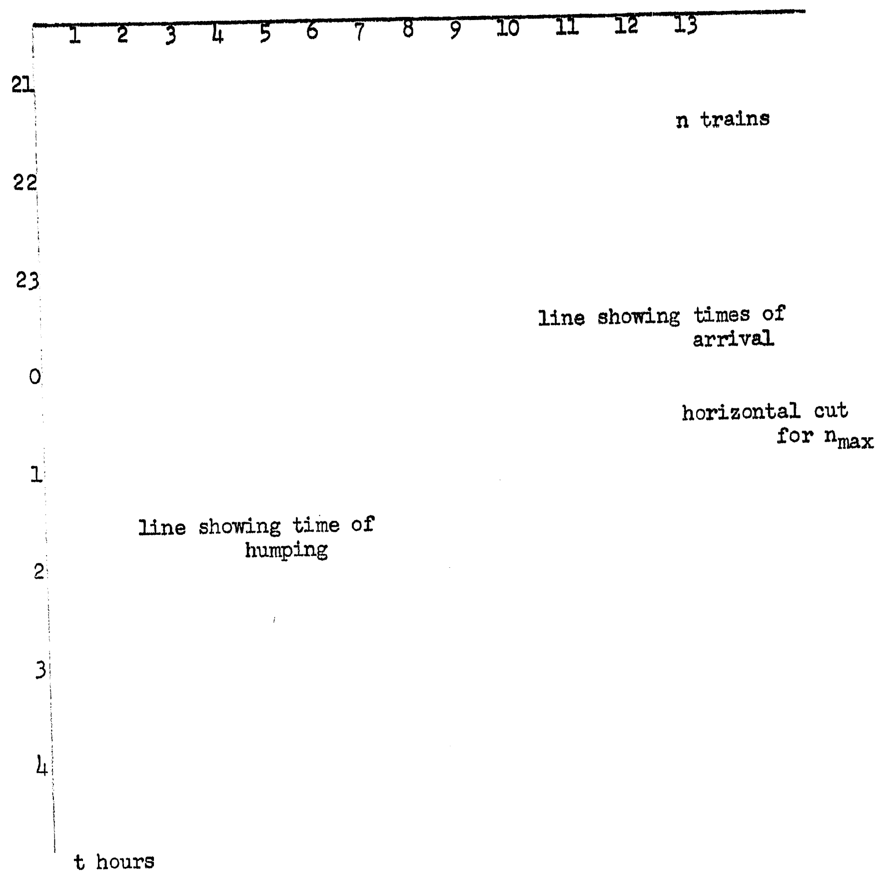

Diagram 1

2232. In Diagram 2, we make the unfavorable supposition that the trains in a group follow each other at equal intervals of z hours. Every c hours a train is humped. Since the group of tracks is supposedly empty when train number 0 arrives, this train may be humped as soon as preparatory operations have been completed. Train number N has the longest waiting time, which is $w_{max} \doteq (c - z)N$. The median waiting time of all trains in the group is $w_m \doteq (c - z)\ N/2$ hours. The time required for processing the entire peak load is $H = cN$. If, for instance, $N = 12$; $c = 0.43$ hours per train and $z = 0.2$ hours per train, then $w_{max} = 2.8$ hours; $w_m = 1.4$ hours and $H = 5.2$ hours.

2233. Instead of the simplifications of the lines showing times of arrival and humping given in Diagram 2, it is also possible to use other curve-smoothing forms such as, for instance, a parabolic curve for the times of arrival. In this case too it is possible to determine the maximum and median waiting times and the time required for processing a group of trains. In the foregoing examples it was assumed that trains would be humped in the order of their arrival. In practice, departures are made from this order to assure that cars arriving on incoming trains connect with the proper departing trains. This does not change the median waiting time, since the increased waiting time of one train is equal to the decreased waiting time of another.

23. Track Utilization Plan and Minimum Number of Tracks

Having the sums of the processing times b (section 21) and waiting times w (section 22) of each train, it is possible to formulate a track utilization plan, when the number of tracks in the group is fixed. Using the same figures one may also determine the minimum number of tracks necessary. In Diagram 1, for instance, one runs a horizontal cut through the lines indicating track occupancy at all possible times and counts the number of trains through which the cut passes. It appears that at most $n_{max} = 6$ trains are simultaneously in the track group. Maximum occupancy is reached when the arrival line runs parallel to the humping line, that is, when the train with the maximum waiting time arrives.

In the case of a straight arrival line (Diagram 2) there are upon arrival of the last train $n_{max} = N - zN/c + b/c = (c - z)N + b)/c$ trains in the group of tracks.

If $N = 12$; $c = 0.43$ hours per train, $z = 0.2$ hours per train and $b = 1.5$ hours, then $n_{max} = 10$ trains.

The greatest number of trains which may be present at any one time is simultaneously the minimum necessary number of tracks in the entrance group: $m_{min} = n_{max}$.

The track utilization plan is to be considered for the period H during which a group of incoming trains is processed. At the beginning and end of this period the tracks are empty or, to be more specific, the first and last trains of the group may be processed without delay. Diagrams 1 and 2 were constructed to conform to these conditions.

24. Probable Occupancy of Tracks

We have determined the minimum number of tracks in the entrance group under the supposition that trains would arrive according to schedule. Rigid adherence to time tables is, however, not to be expected. Minor irregularities and trains delays may cause deviations from the norm and will cause disturbances in the assignment of tracks unless certain track space is available as to reserve to cover temporary and irregular peaks. The actual number of tracks must therefore, and quite apart from the need for rounding to a whole number, be greater than m_{min}. Consider now this expanded group of tracks during the peak load period H. The N trains processed occupy the tracks for individual times totalling $(b + w_m)N$. During the period H the railroad has track capacity available equal to the number of tracks multiplied by the time, that is mH. The operations cause the tracks to be occupied in the ratio q $(b + w_m)$ N/nH, which we will call median track occupancy. If we assume a straight humping line (H/N = c) and abbreviate $n_m = (b - w_m)/c$, then $q = n/_m m$. [sic: probably should be $q = n_m/m$.]

The probability that a track will be occupied is q. The probability that all m tracks will simultaneously be occupied is, accoring to the laws of probability q^m and the duration of this simultaneous occupancy of all m tracks is $p = Hq^m$. During this time p the group of tracks is not able to receive a further train. A further flow of trains into the yard will therefore be disturbed, and we may designate p as "disturbance time" (item 12 in bibliography). These disturbance times are phenomena which we may observe in actual railroad operation: they are the intervals during which trains must wait outside a yard since all the tracks in the yard are filled. The relationships between n_m, m and $p/H = (n_m/m)_m$ are shown in Diagram 3.

From Diagram 1 we were able to determine that b = 1.5 hours; w_m = 0.52 hours; c = 0.43 hours per train and H = 5.2 hours = 312 minutes. This means that n_m = 4.65. The minimum number of tracks was m_{min} = 6. For various numbers of tracks m the expected disturbances p have been calculated, as follows:

m	q	q^m	p minutes

In the calculations, Emde's table of exponents (item 6 in bibliography) has been used. It is in our case indicated that really disturbance-free operations can be expected only when m is set at at least eight tracks.

3. THE FREIGHT TRAIN TRACKS OF A MEDIUM-SIZED YARD

At a junction various lines merge, which are travelled by through freight trains. These trains stop at the junction station for certain operative steps. These include: passing trains going the other way on single track lines, being overtaken by faster trains, watering the locomotives, and sometimes changing locomotives or dropping or picking up groups of cars. All these activities are determined by the time table and involve an occupancy of tracks, which with the help of the track utilization plan may be converted into a track requirement. The same tracks used for taking care of the through train are also used for assembling short-distance freight trains leaving the station in various directions. For this operation too the occupancy time and track need may be determined. This problem is different from that presented in subhead 2, since it was there assumed that all tracks could substitute for each other. In the case to be examined here, some of the tracks are accessible only from the through tracks in one direction, the others only by way of the through tracks in the other direction. It is thus necessary to set up the track utilization plan separately for each part of the group, and to calculate separately the necessary reserve tracks needed in each part to eliminate traffic disturbances. Some relief may be afforded when, for instance, the center tracks may be connected to through ways on each side, so that they may be used in either direction. It may be the case that the peak loads in the two directions do not occur at the same time. It is then possible for tracks in the two subgroups to substitute for each other; but it is doubtful whether the alternation of peaks can be expected at all times. It is advisable to provide at least for possible expansion so as to provide enough tracks so that peak loads in both directions can be handled at the same time.

An example will illustrate how the total of expected disturbances is calculated. Let us assume that in a station the peak load period H is 6 hours and that during this time tracks in the two directions OW and WO are occupied, a total of 9 hours in each direction. This would mean that $9/6 = 1.5$ tracks would be necessary in each direction.

Case A: There are 3 tracks in each direction, but the tracks of the two sub-groups cannot substitute for each other. The probable total disturbance in each sub-group is the $p = 6(1.5/3)^3 = 0.75$ hours. The combined total disturbance for both sub-groups is $P_A = 2 \cdot 0.75 = 1.5$ hours, that is to say, fairly high.

Case B: There are 6 tracks, of which the two outer pairs can each be used in only one direction, the two center tracks, however, in either direction. The probability that two trains in one direction are present in the yard is $(1.5/2)^2 = 0.5625$; that three trains in one direction are present $(1.5/3)^3 = 0.125$ and for four trains in one direction it is $(1.5/4)^4 = 0.0198$. The probability that either 2 OW and 4 WO trains, 3 OW and 3 WO trains or 4 OW and 2 WO trains are present at one time, thus occupying all available tracks, is: $0.5625 \cdot 0.0198 + 0.125 \cdot + 0.198 \cdot 0.5625 = 0.0379$. This means that the total expected disturbance in this case, P_B, is only $0.0379 \cdot 6 = 0.23$ hours.

In both cases A and B there are six tracks. The possibility of using the center pair of tracks in both directions reduced the total expected disturbance to about 1/6 what it would be otherwise.

4. PLATFORM TRACKS

In addition to operating activities taking place on platform tracks, such as passing and overtaking, watering or changing locomotives, adding or taking off inter-line cars, there are also traffic activities, that is to say the boarding and alighting of passengers and the loading and unloading of baggage, express and mail. The minimum times required for platform stops may be calculated and must be added to the time required for moving in and out of the track to determine the total time the track is occupied. The track occupancy time of a passenger train is usually much shorter than those of the freight trains considered in the preceding subheads. For this reason a much more important consideration in the case of passenger trains is the waiting time caused by the fact that various possible through passage ways are mutually exclusive. In the case of yards which present operating difficulties, waiting time for a clear passage out of the yard may be many times the minimum time the train stops at the platform for operating and traffic purposes. A careful coordination between the number of platform tracks and the development of the yard as a whole is therefore a condition for achieving a low disturbance factor, and simultaneously the guarantee for efficient and frictionless operation. The remarks concerning the substitution of tracks for each other made in Subhead 3 apply equally to the case of platform tracks.

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