The railway level crossing: Synergy effects between rail and road infrastructure capacity

Martin Sojka, Swiss Federal Institute of Technology (ETH)[1]

Conference paper STRC 2016

STRC | 16th Swiss Transport Research Conference
Monte Verità / Ascona, May 18-20, 2016

The railway level crossing: Synergy effects between rail and road infrastructure capacity

Martin Sojka
Swiss Federal Institute of Technology (ETH)[1]
Zurich

Phone: +41 44 633 21 63
Fax: +41 44 633 10 57
email: martin.sojka@ivt.baug.ethz.ch

May 2016

Abstract

Railway traffic is growing rapidly in European urban and suburban areas. Railway infrastructure shares in such areas the public space with other transport modes and is typically situated on the same high level as other transport infrastructures. Such situation causes building and maintaining of the level crossings, which have to be equipped with safety installation to prevent level crossing accidents. These specific bottlenecks cannot be easily removed because this is generally impossible (e.g. urban structure) or it could be achieved only by considerable investing in road and/or rail infrastructure.

Level crossing control system does not differentiate between different train categories and operates as a normal interlocking system. Therefore this system automatically counts with the worst possible situation and keeps the level crossing closed for a long time which is not always needed. Thanks to the development of advanced railway traffic management systems and new signalling systems is now possible to diversify level crossing closing times. The trains will be divided into several train groups (categories) and differentiated from other ones by running time. Closing time will be optimized for each of this different group (or train). Without limiting railway traffic or railway infrastructure capacity it is feasible to increase the road infrastructure capacity of such level crossings significantly without having to build and/or maintain an additional road infrastructure.

Keywords

railway level crossing, railway crossing, level crossing, train crossing, level crossing safety, ETCS, railway capacity, road capacity, synergy effects

[1]Author works at ETH, but studies as doctoral student at Czech Technical University in Prague.

1. Introduction

Railway traffic as well as road traffic are growing rapidly in European urban and suburban areas. Railway and road infrastructure shares in such areas the public space with other transport modes. Although the railway and the road infrastructure are usually spatially separated from other transport modes, they are also typically situated on the same high level as other transport infrastructures. This situation inevitably leads to common areas, where these two infrastructures exist simultaneously, but where the interests of different transport modes conflict.

2. The railway level crossing

The railway level crossing is called the place where the railway and road infrastructures are crossing on the same level. These places work similarly as an intersection of two roads where direction change is not permitted and only vehicles on the same road could move freely through.

At railway level crossing, road vehicle drivers have to give way trains. It is due to technical specifications of railway vehicles. Railway vehicles have a very long braking distance based on low coefficient of adhesion between steel wheel and steel rail leading to impossibility of stopping or slowing down rapidly. That is why the trains have to move in block section in which whole railway infrastructure is divided. The railway operations between block sections are controlled by signals, which sufficiently in advance inform about the option to continue in a next block section. Road transport with high coefficient of adhesion is operated in line-of-sight distance mode. At the railway level crossing road and rail traffic share the same infrastructure. Because it is not possible to use the infrastructure by both transport modes at the same time, the railway has a priority.

The combination of road traffic as continuous function with rail traffic as discrete function fitted for a long time very good together. With the extremely growing intensity of road transport in the last decades, especially in urban and suburban areas, a solution improving road safety[2][3] and road capacity for the railway crossing was sought. Where especially capacity has to be improved, one of the best solutions represent always the level-free solution. But not all these crossings can be easily replaced by level-free solution like overpass or underpass because this can be generally impossible (e.g. urban structure) or it could be achieved only by considerable investing in road and/or rail infrastructure. This situation causes building and maintaining of the level crossings, which must be equipped with safety installations to prevent level crossing accidents. These level crossings are called protected level crossings.

The number of level crossings in operation is reduced by every year in Europe, nevertheless on the territory of EU-28 and EFTA-States are still together about 122‘000 active

[2] Improving the safety of level crossings increase especially the road transport safety because the major negative impact is nearly always on the side of road transport.

[3] This statement is widely used by railway infrastructure managers, means level-crossing safety is often viewed as a road-safety problem[7].

level crossings[4]. Their number is decreasing with a continuous speed of about 2% per year during last years across Europe[7]. Although the number of level crossings in operation is shrinking, the number of level crossing with protection system, which comprises about 50% of the total number of level crossing, remains enormous.

2.1 Level crossing capacity

The capacity of railway level crossing can be defined from railway or road point of view. Both transport modes have own measure units. But for mixed view, there is a lack of common measure system and universal units. Train operations are prioritised at railway crossing, theoretically until the entire capacity is used. Therefore calculating only the remaining road capacity can already be considered as sufficient.

2.1.1 Level crossing capacity allocation

Capacity of railway level crossing consists of railway and road capacity part. The railway demands capacity only if train is coming and the necessary capacity is then reserved with priority (either supported by technique or at passive crossing through right of way). The road transport uses remaining capacity. In practise, road transport uses only one part of the remaining capacity and the rest stays as general reserve. Even if enough reserves exist in the system, the delay appears systematically, because the almost continuous flow of road traffic is regularly disturbed by trains. In these moments road traffic is stopped and delayed even if the level crossing capacity is widely not reached.

In the case of real lack on capacity, which means the requirements of both transport modes is not possible to satisfy over a longer period of time, the real impact affects road transport mode only. The railway system does not need any additional capacity, because if necessary, the whole capacity will be allocated for the railway use only.

2.2 Level crossing closing time

Synergy effects between rail and road infrastructure capacity and therefore additional capacity can be found in the level crossing closing time. This time period represents time slots, when the level crossing is blocked for one or more train movements. This „blocking“ is

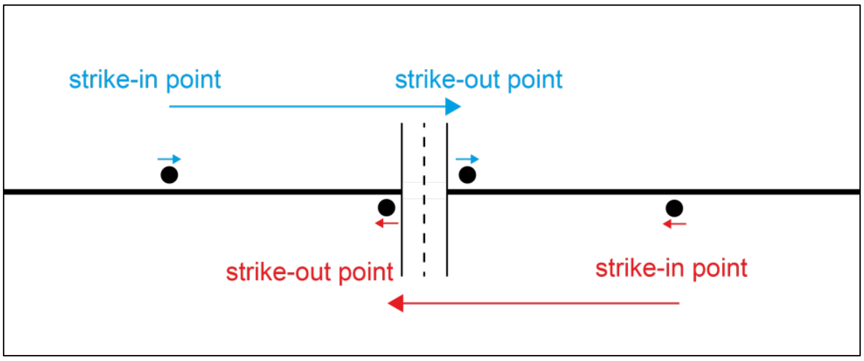
[4] Data have been collected and counted from: Railway safety performance in the European Union 2014, European Railway Agency, France, 2014[7]; Inventarliste Bahnübergänge, UVEK/BAV, Switzerland, 2015[3]; Jernbanestatistikk 2014, Jernbaneverket, Norway, 2015[4].

done either direct by road users in case of passive (unprotected) level crossing according road traffic regulations or by level crossing protection system in case of active (protected) level crossing.

Especially in the case of active level crossing, the time slots are not always used effectively. This inefficiency in capacity use is directly linked to a primary aim of all level crossing control systems, which is safety. The level crossing protecting system works on the fail-safe principle with one or more strike-in and strike-out points without any additional information about the train.

Different train categories use the railway line in different ways according to their physical characteristics (like weight, length, maximum speed, traction power, adhesion ratio etc.) or to the role they have to ensure (stopping pattern, timetable policy). As a fail-safe solution, which takes into account the worst possible situation, the level crossing protection system is designed to activate before any train could reach the level crossing. Therefore, the strike-in points are so far away from the crossing to guarantee, that also the fastest possible train reach already closed level crossing (Figure 1).

Figure 1 Active level crossing working principle



But the level crossing protection system can not differentiate between different train categories and operates as a normal part of an interlocking system. When a slower train approaches and activates the strike-in point, level crossing protection system activates immediately as usual and keeps the level crossing closed until the train passes. Due to different characteristics of such trains as well as technical features of the protecting system and safety reasons, the level crossing remain closed for a longer time than necessarily needed. A schematic overview of the basic set of technical parameters which significantly influence and extend the closing time of level crossing illustrates the following Table 1.

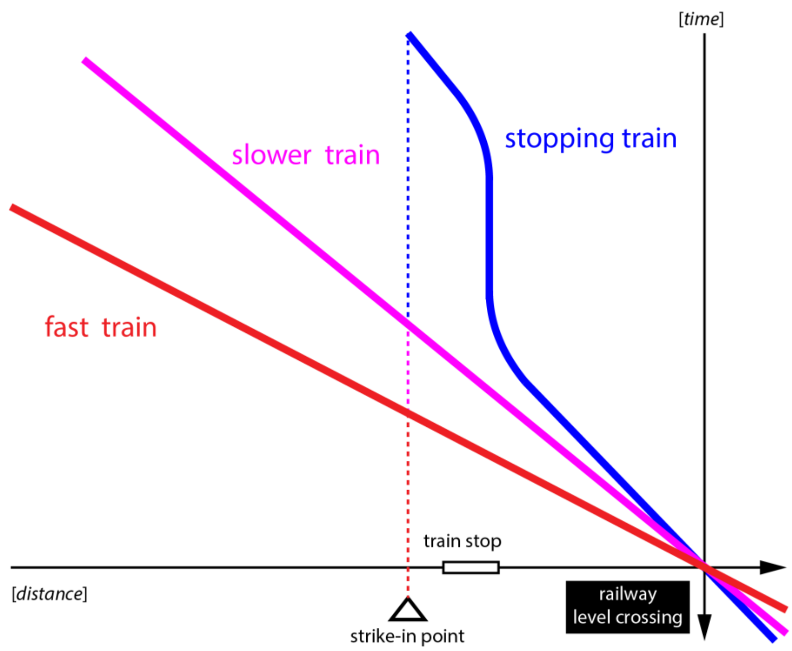
Table 1 Parameters with impact on closing time of level crossing

<table>
<tr><td colspan="3">Railway side</td><td>Road side</td></tr>
<tr><td>Infrastructure</td><td>Rolling stock</td><td>Timetable</td><td rowspan="5">none</td></tr>
<tr><td>signalling system
• position
• type of signal
• signal aspects</td><td rowspan="4">difference between trains in
• speed
• acceleration
• length*
• weight*</td><td rowspan="4">train stop policy</td></tr>
<tr><td>train stop
• distance to level crossing
• distance to signal</td></tr>
<tr><td>distance to the railway station</td></tr>
<tr><td>number of tracks</td></tr>
</table>

** normally without a significant impact on closing times*

The parameter with biggest impact is definitely the existence of a train stop in front of the level crossing for the stopping trains only, followed by difference in the speed between theoretical fastest and current train. Figure 2 roughly illustrates the difference in time consumption between non-stop train, slower non-stop train and train stopping in station/at stop and represents the overall situation nowadays without splitting train into different groups.

Figure 2 Time/distance diagram of non-stop train, slower non-stop train and stopping train approaching level crossing



Numerical solution to this problem is not trivial. Without precise knowledge of the parameters, the time loss can be only estimated. Presuming the typical top speed of stopping train about 130 km/h, non-stop fast train using same speed limit and an ideal train stop location, the additional time consumption will be around 60 seconds[5].

For a given combination of parameters, it is a fitting example. With higher maximum track speed, not well suited stop location, another distance to the level crossing or especially longer stop times, the time difference could be significantly higher than the value mentioned. For the slower non-stop trains like freight ones, the absolute time difference is 2-3 times lower than for stopping trains. Much more serious scenario would follow if more stops would be set between strike-in point and level crossing. The stopping train in the first stop could already activate the level crossing protection system. Such situation will cause over-proportional increase of level crossing closing time, but the probability of the corresponding conditions is low.

[5] calculated with typical comfort acceleration and deceleration criterions, short stop time included.

3. Use of railway traffic control systems

Thanks to the development of advanced railway traffic management systems and partially also new signalling systems is possible to diversify level crossing closing time according to the different train characteristics. Railway traffic management systems nowadays automatically prepared train path and control the allocation of all train paths in real time.

Planned timetable, nominal-actual comparison of the planned and real situation as well as implementing rules support operational decision by traffic managing. In this case is elementary to identify each train means all train must be equipped with unique number, so called train number. This information could be used for dividing trains into several train groups (categories), which differ significantly from other ones in defined important parameters (see Table 1, section rolling stock and timetable).

Closing time can be theoretically optimized for each of these different groups (or trains). The major disadvantage of this option is set by safety function of level crossing protection system. This constrains does not allow to assume everything works in a correct and safe way, but it really must operates in a safe way.

This above mentioned situation can be solved by signalling system only. If the level crossing is protected by closed signal, road traffic is not disturb. Before the train comes, the level crossing protection system actives and level crossing closes, then the signal opens and the train passes the level crossing. In case of mistake or malfunction the railway crossing blocks the road traffic unnecessarily or in the opposite case, the fast train without open signal has to decelerate or to stop in front of the closed signal. None of these situations are eligible, but from safety point of view do not cause any risk or compromise the railway and road safety.

Difficult task to solve is to reserve the train path as late as possible to prevent early closing of level crossing and on the other side signal has to be open ahead of the train to prevent brake usage. Following the example of Figure 2, the difference between fast train and slower train like freight train, some brake profiles for typical freight trains have been checked (according to the minimal freight wagon braking standards of UIC[8] and RTE-Norm[6]). Always when the level crossing closing time multiplies with the train speed in to distance, which is longer than signal spacing between distant signal and main signal including also the response time of the train driver, the potential for time saving is available. This solution is limited by the flexibility of the system components like human factor and therefore the applicability need to be considered in detail. The stopping train problematic is graphically presented in Figure 2 as well as described in chapter 2.3.

A further option is to use the new European Train Control System (ETCS), which enable from level 2 to add practically infinite number of signal points on the line. Therefore there will be no problem with some additional signal points or negative impact on other train operations. The question of braking curve used in ETCS for controlling the trains going to closed signals could be the limiting factor for use this technology. This option need to be checked in detail.

Without limiting railway traffic or railway infrastructure capacity it is feasible to increase the road infrastructure capacity of such level crossings significantly without having to build and/or maintain an additional road infrastructure, especially if trains stop there.

3.1 Estimated effects in Zurich metropolitan area

In Switzerland the solution with additional signal is in some situation already used, but still primarily by manual intervention of traffic controller and only in cases where already such main signal exists and where also an additional train stop is located, but not systematically implemented and automatically used.

For simplified analysis of the overall benefits related to time savings, the whole railway network of Zurich metropolitan area have been chosen. The network is defined as the whole normal and narrow gauge railway network in the canton Zurich including railway lines located outside of canton, if on the additional line “S-Bahn“ train service is provided and such train line serves at least one station within the territory of the canton Zurich. The level crossing statistics shows Table 2.

Table 2 Level crossing statistic in Zurich metropolitan area

Total amount of level crossings	352
of which are	
• in station	117
• in vicinity of station	55
• on open line	180
with traffic volume of motorised individual transport (MIT 2013)*	
• without information	240
• < 500 vehicles/day	7
• < 2’000 vehicles/day	32
• < 10’000 vehicles/day	64
• > 10’000 vehicles/day	9

*Source: *[2], otherwise author*

Estimation of total delay time of motorised individual transport is based on very simplified calculation, which expects the train service on each line as follows: 1 fast train pair, 1 freight train pair and 4 regional train pairs every hour of the day. For all train paths are presumed fixed maximal time savings of motorized individual transport according to chapter 2.2. Summing the additional time consumption for all the level crossing over the average day, possible time savings of about 359 hours daily or about 131’000 hours during one year are expected.

4. Summarizing the overall benefits

While is here spoken about synergy effects between rail and road infrastructure capacity, is the goal of the paper in redistributing the overall capacity with a new proposed system which is likely to raise the road capacity and safe the time of road transport without reducing the railway capacity.

The assets are raising total capacity of the transport infrastructure and cost saving due to time reduction in road system. Indirect benefits through increased acceptance for railway operation may be also expected. This solution would also bring a considerable added value and improve the overall safety of railway level crossing. All road users like drivers or pedestrians would know, that trains are coming immediately after begin of warning time and would not so much risk trying to cross closed level crossing thinking the train is coming later. For the same reason, warning time minimising is usually required by national laws or by technical standards for building and renewing of active level crossings in Europe.

5. References

[1] Ausführungsbestimmungen zur Eisenbahnverordnung (AB-EBV), Bundesamt für Verkehr BAV, Bern, 2014.

[2] Gesamtverkehrsmodells des Kantons Zürich (GVM-ZH), http://maps.zh.ch/, Canton Zurich, 2016.

[3] Inventarliste Bahnübergänge, Eidgenössisches Departement für Umwelt, Verkehr, Energie und Kommunikation UVEK, Bundesamt für Verkehr BAV, Bern, Switzerland, 2015.

[4] Jernbanestatistikk 2014, Jernbaneverket, Oslo, 2015.

[5] R RTE 25931 (SN 671 512) Bahnübergang, Basisdokumentation, Verband öffentlicher Verkehr (VöV), Bern, 2012.

[6] RTE 29100 Vorsignaldistanzen, Normalspur, Verband öffentlicher Verkehr (VöV), Bern, 2014.

[7] Railway safety performance in the European Union 2014, European Railway Agency, Valenciennes, France, 2014.

[8] UIC-Leaflet 543 Brakes – Regulations governing the equipment of trailing stock, Paris, France, 2007.