6 Cost Benefit Analysis for OTI – Methodology and Results

Alessa Isberner, Benedikt Scheier, Florian Brinkmann; DLR, Braunschweig, Germany

6.1 Introduction and Aim

A study performed on Network Rail and Deutsche Bahn real scenarios for regional and high capacity lines has been conducted about the life cycle costs for on-board train integrity control (OTI) being developed within X2Rail-4 project of Shift2Rail. The expected costs were compared to the saving potential through the elimination of infrastructure components. The following advantages of shifting the train integrity control from the track to the train are expected: On the one hand, the energy supply, maintenance, servicing and reinvestment of trackside elements such as axle counters and track circuits are significant cost factors that represent an economic disadvantage, especially on lines with a low density of trains and short block distances. It can therefore be assumed that a cost saving can be realised here through OTI. On the other hand, the saved costs of the field elements must be compared against the costs for the additional train equipment. Further calculations have been performed on the cost difference of retrofitting with SIL-2 or SIL-4 devices.

Furthermore, a simulation model has been used to investigate the effects on capacity when operating with moving block for which OTI is an enabler. For the analysis of capacity gains through moving block, two high-density lines with mixed traffic and one low density line have been chosen. Of the two high density lines one is located between Offenburg and Freiburg in Germany, the other one is a section of the West Coast Main Line (WCML) in the United Kingdom (UK). The low-density line is located in Wales (UK). In addition to the line capacity analysis, the effects of applying moving block in nodes and stations has been investigated. Due to the different approaches of reserving track sections, differences in the occupation of tracks in the node and therefore differences in the headway are expected. Here, an additional improvement can be expected for lines with high density of trains and nodes that are at their capacity limits [1,2].

6.2 Methodology and Results

6.2.1 Life Cycle Cost Analysis

A Life Cycle Cost (LCC) analysis based on the Net Present Value (NPV) approach has been performed in order to evaluate the changes in the cost structure. The LCC approach is useful for assessing technological implementations with a long service life.

$$NPV = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+i)^t}$$

Equation 6-1: Calculation of the Net Present Value where t = year under consideration, Bt = benefits in year t, Ct = costs in year t, T = lifespan of the project (in this case 30 years), i = discount rate in year t (in this case 3%) [3].

The cost calculation and determination of the number of trains which are relevant for each scenario has been described in detail at the SmartRaCon Conference 2020 [4].

Results of the analysis show that on the Cambrian line in Wales, costs can be saved even if 50% of the trackside elements remain installed (see Figure 6-1). Reasons are that no freight trains are running and only one passenger train service every hour. This means that only few trains have to be fitted with the new OTI technology. At the same time, a lot of trackside infrastructure is on the line, making it expensive. On the other two lines, the number of trains that need to be equipped with the new technology is much higher. This has the result that the cost ratio is only positive when most of the trackside elements can be removed (10% remain on WCML and 25% Offenburg scenario). A limitation of these results has been the sole focus on regional and freight traffic (not including high speed trains and potential costs for retrofitting), thus the real numbers are assumed to be lower [5].

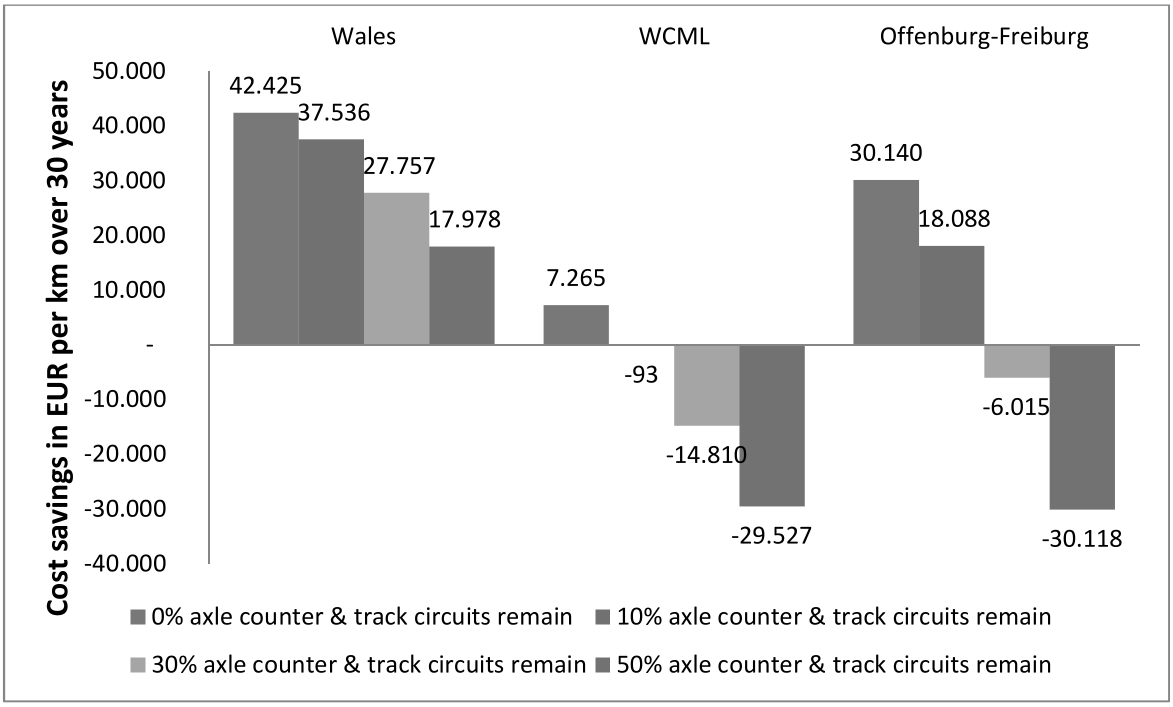

Figure 6-1: Cost savings per km for different amount of trackside infrastructure

Further calculations have been performed on the cost difference of retrofitting with SIL-2 or SIL-4 devices. As cost estimations for a SIL-2 device have only been available from expert estimation, the overall costs for the SIL-2 OTI device have been assumed to lie in a range of 50%-70% of the costs of a SIL-4 product. The results of Figure 6-2 show that the main lever are freight trains as the cost to equip freight trains with OTI technology is a lot more cost intensive due to every freight vehicle needing to be equipped, and higher costs for wireless solutions (when compared to fixed-formation passenger trains) [1].

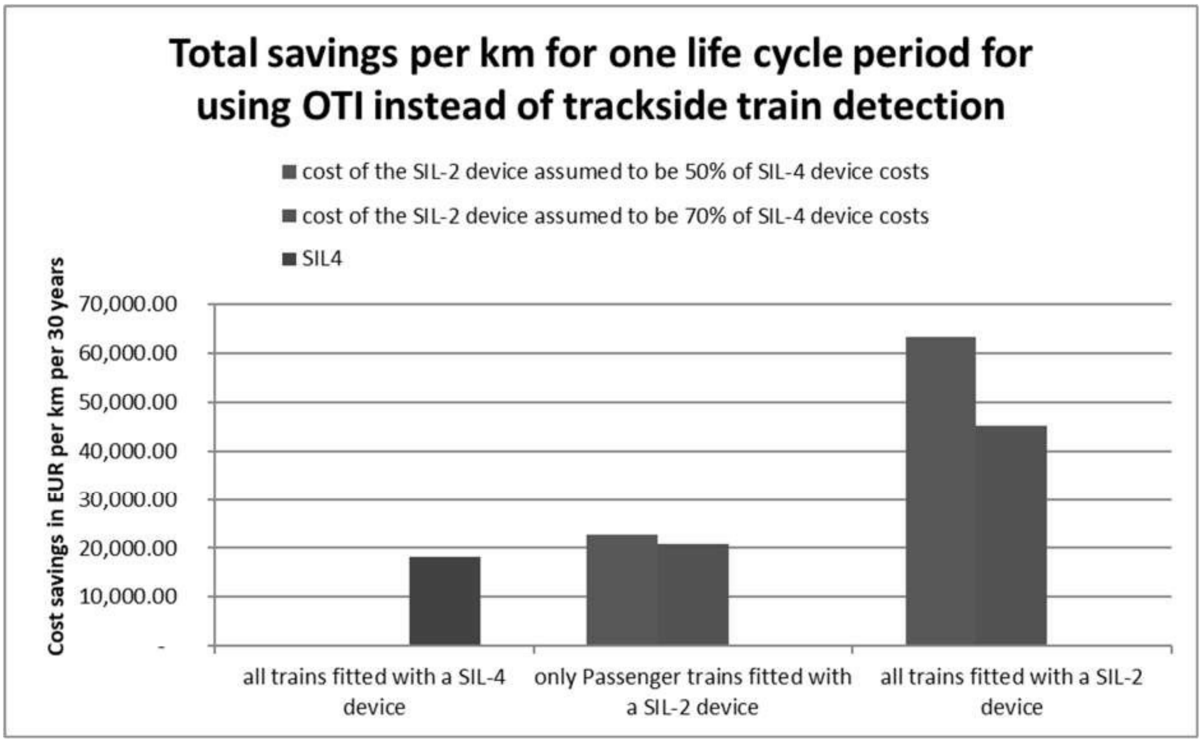

Figure 6-2: Cost savings in the Offenburg scenario with a SIL-2 device

6.2.2 Capacity Analysis

For the investigation on the effects of applying moving block in nodes and stations in the specific scenarios, a microscopic simulation has been applied, because detailed models of trains as well as the infrastructure (e.g. switch positions) are needed. The simulation tool OpenTrack of the Swiss company OpenTrack Railway Technology Ltd was used for the microscopic simulation as it provides the possibility to apply moving block operation [6]. The critical areas in the analysed corridor are in front of Freiburg and Offenburg where additional regional train lines merge onto the main line. In Offenburg an additional factor that limits capacity is the fact that some of the freight trains need to cross through the oncoming traffic as they need to merge into the marshalling yard. Even though the block distance in these areas is already very short with 1-1.5 km, the capacity consumption is lowered from around 80% to 55% (evaluation of capacity consumption according to UIC Code 406) [7], meaning an improvement to the recommended value for maintaining satisfactory operating quality. Figure 6-3 shows two train diagrams of a section of the analysed corridor with fixed blocks (left) and moving block approach (right). On the x-axis the distance of the section is shown and on the y-axis the time. The grey shaded areas visualise the time that a track section is blocked by one train thus showing bigger stairs shaped areas when the legacy system uses fixed blocks.

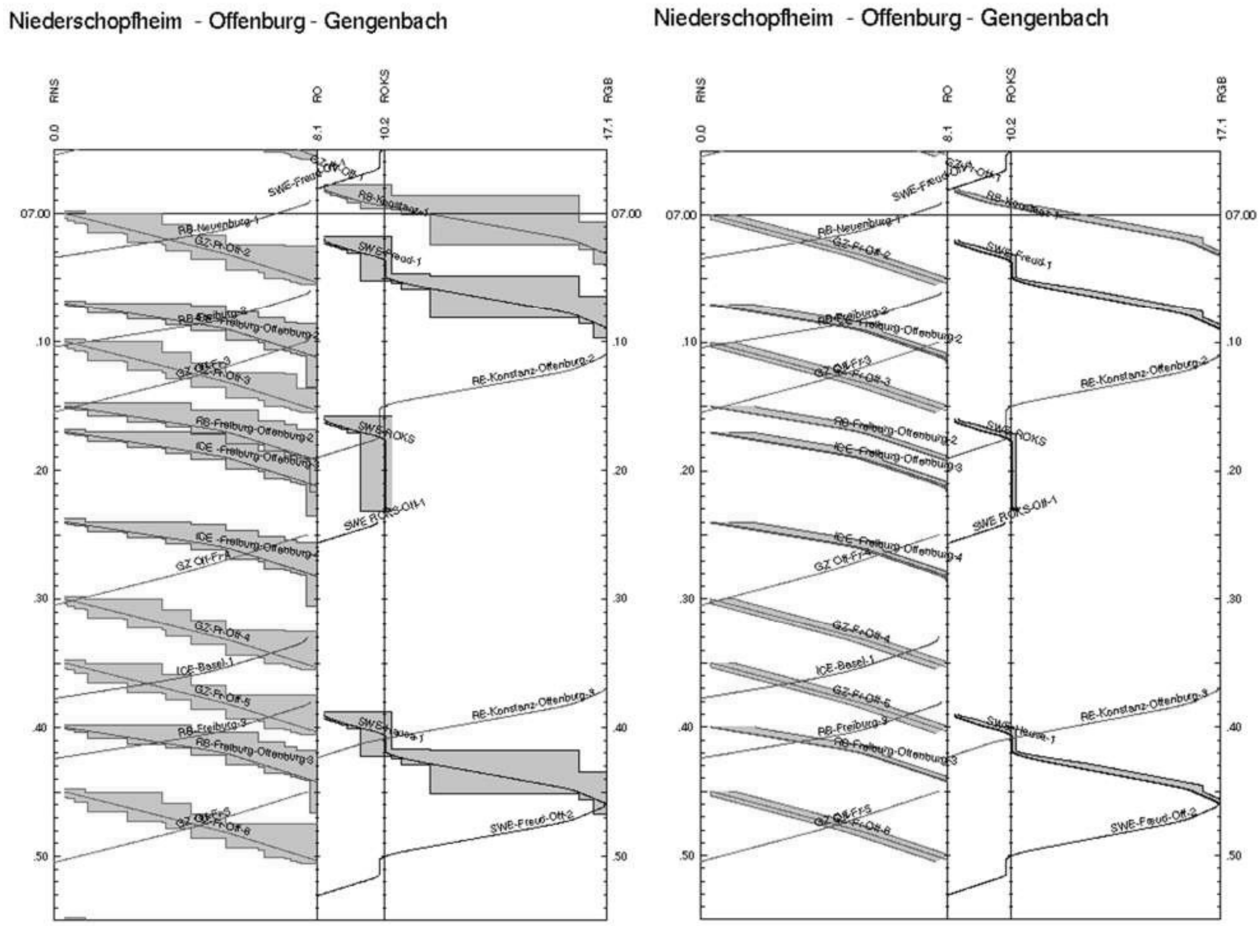

Figure 6-3: Train diagram between Freiburg and Offenburg with current fixed block (left) moving block approach (right)

Even though, the gain in capacity has not been monetarised as it can only be partially attributed to the OTI technology it is an important benefit. It shows that there are additional factors besides the direct costs that are important to consider when making an economic comparison between on-board and trackside infrastructure functionalities [2].

With moving block operation, an increase in capacity can also be achieved in nodes. The occupation rate of the critical switches and crossings in the Moving Block scenario in Offenburg station (see Figure 6-4), could be reduced to about 50% - 33% compared to the fixed block scenario (see Table 6-1) [2]. The location of the switches and crossings analysed are visualised in Figure 6-4 and the results documented in Table 6-1.

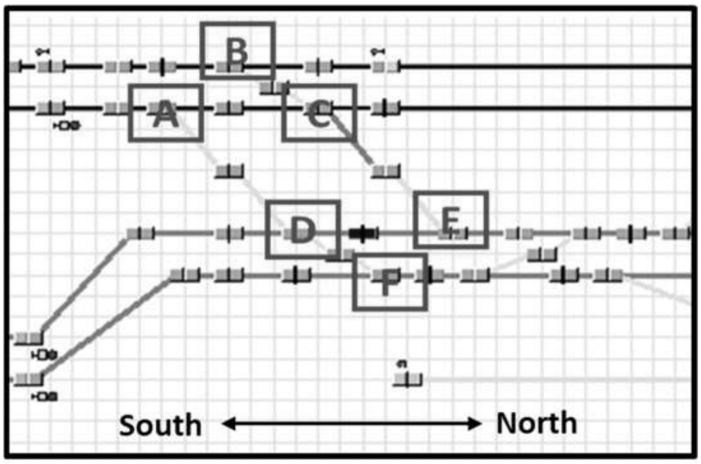

Figure 6-4: Node-edge model of Offenburg station with switches and crossings (A-F)

Table 6-1: Occupation rate of relevant switches and crossings in Offenburg station (A-F)

Switch/ crossing	Fixed block occupation rate [%]	Moving block occupation rate [%]	Occupation level of switch/crossing
A	32.2	9.6	Bottleneck 1: highly occupied switch; all trains coming from the South need to cross here
B	19.2	8.1	Medium occupied switch; all trains coming from the North cross here
C	28.2	9.5	Bottleneck 2: same level crossing of freight traffic coming from North with passenger traffic coming from south
D	24.4	8.8	Medium high occupied switch; freight traffic coming from South crossing traffic coming from side line
E	19.2	9.3	Medium occupied switch; freight traffic coming from the South is crossing traffic coming from side line; interesting fact, moving block effect is not as high as for other points
F	23.7	7.6	Medium high occupied switch, freight traffic coming from the South crossing passenger traffic coming from the side line

6.3 Conclusion

Train integrity monitoring with trackside equipment was compared to the onboard train integrity with on-board unit. For low density lines, the results show that train integrity monitoring with on-board units is more economical due to the limited amount of trains that need to be equipped and the high costs for the infrastructure elements.

For high density mixed lines, the break-even point between both technologies under the stated assumptions was between a level of remaining trackside elements of 10-25%.

The track circuits and axle counters on the infrastructure however do not solely monitor train integrity but also provide the location of the train. When trackside elements are removed it has to be considered that the functionality of safe train positioning and the determination of the train length are safety relevant information that needs to be provided. For this reason, the additional functionality of train length determination has been added to the project, however this had been done at an advanced stage of the project after the analysis which is described here had been performed.

From the capacity analysis it can be concluded that with moving block operation, an increase in line capacity as well as the capacity in the analysed station is possible. Whether this is only the case for this specific station or whether it can be transferred to other stations has not yet been investigated.

6.4 References

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6.5 Acknowledgements

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6.6 Authors

Alessa Isberner is scientific staff at the Institute of Transportation Systems of the German Aerospace Center since 2018 after graduating from the Institute of Transport Studies (ITS) at the University of Leeds. She works in the X2Rail-4 project on the Cost-Benefit Analysis of the On-board Train Integrity technology.

E-Mail: Alessa.isberner@dlr.de

Benedikt Scheier is scientific staff at the Institute of Transportation Systems of the German Aerospace Center since 2007. His focus is on the design and impact assessment of new transportation technologies and innovative mobility concepts.

E-Mail: Benedikt.Scheier@dlr.de

Florian Brinkmann is team leader at the Institute of Transportation Systems of the German Aerospace Center. The focus of his research group is the design and impact assessment of new transportation technologies and innovative mobility concepts.

E-Mail: Florian.Brinkmann@dlr.de