9 CBA – Assessment methodology for shifting railway technology from the infrastructure onto the train

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9.1 Introduction

At the moment, research on railway technology in the field control command and signalling is exploring options that shift functionalities from the infrastructure onto the trains. [1] One example is the assurance of the integrity of the train, which is currently implemented through axle counters or track circuits. The Cost-Benefit Analysis (CBA) that is being done in the Shift2Rail project X2Rail-2 Work Package (WP) 4 is not performed at a stage of selecting and comparing different technologies against each other but to disclose the cost and benefits of shifting the train integrity function from the infrastructure onto the train. One part of this cost benefit analysis is an analysis of changes in the life cycle costs of the technology.

9.2 Life Cycle Cost Methodology

The purpose of this abstract is to present a methodology for ensuring an accurate cost comparison of fixed infrastructure components that can be directly attributed to a specific location, with costs related to a moving asset such as locomotives and wagons.

9.2.1 Life cycle cost calculation

Area of investigation

When analysing indicators of a system such as costs, the first step is to find a decision on the area of investigation. Generic scenarios have to the advantage that they simplify complexity, reducing regional specifics of a certain corridor. This has the advantage that results can be extrapolated on a high level but will lack detail and an exact representation of the system.

To capture the effects of a single functionality of the railway system however, detail is often important as average values do not show all aspects.

Within X2Rail-2 WP4 it has therefore been decided to perform the CBA on different real life scenarios, thus capturing different railway corridors in various countries with their respective regional specifications. These scenarios were carefully chosen in order to be typical and representative for a certain part of the railway network.

Functionality analysis

In another step it has to be analysed which functionalities are covered by the old technology on the trackside and how they are covered by the new on-board unit. In the X2Rail-2 WP4 case, axle counters do not only monitor train integrity but also provide information on the safe train positioning. This does not mean that the cost for the two functionalities of monitoring train integrity cannot be compared to each other but all assumptions and prerequisites have to be stated in order to ensure an objective interpretation of the result.

Net present value approach

For all assets of infrastructure elements and on-board unit, the lifespan, capital expenditure (CapEx) as well as operational expenditure (OpEx) have been collected and discounted over a period decided on depending on the project as can be seen in Figure 9-1. For railway projects a common time period is 30 years. This is especially important when comparing projects with different lifespan where some are very long as the value of money changes over time [2].

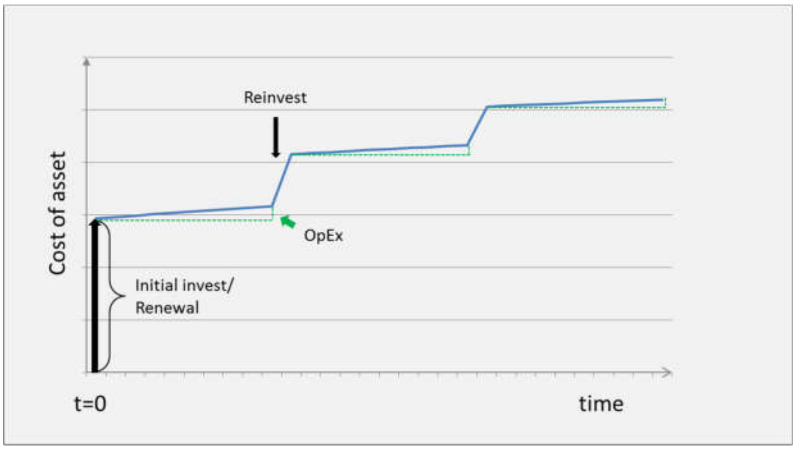


Figure 9-1: LCC infrastructure asset

The CapEx include all initial investments as well as reinvests of asset components with a shorter lifespan that have to be replaced within the common time period. In the OpEx all cost that arise continuously, in this case maintenance cost and operational cost are included. Due to the compound interest effect, inflation and opportunity cost, the value of money changes over time. Especially for assets with long life cycles it is therefore important to discount all cost that occur over the life span of the asset to the same time. This is done with the net present value (NPV) approach. Usually all costs are calculated to the present time (t=0) [3]:

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

Where B_t = benefits in year t, C_t = costs in year t, T = lifespan of the project and i = discount rate in year t

9.2.2 Life Cycle Cost for fixed assets

For the infrastructure elements the cost can then be calculated by multiplying the number of assets within the area of investigation and the cost for each asset. As infrastructure assets have a fixed location the allocation to an area can be done. When infrastructure elements become obsolete, the benefit equals the costs per asset multiplied by the number of infrastructure elements. When a specific amount of the infrastructure assets need to remain to ensure backward compatibility it is more challenging to determine the exact number of infrastructure elements that become obsolete and therefore contribute to the benefit in the form of cost savings. This is however not part of the analysis done in the X2Rail-2 project and therefore not further investigated here.

9.2.3 Life Cycle Cost for moving assets

The cost calculation for the trains however is more complicated as they do not run exclusively in the scenarios chosen but are used within a wider network.

Therefore an approach has been developed to estimate the number of trains that correspond to a defined corridor under the assumption that not only this corridor but the whole network will in fact be fitted with the new technology.

9.2.3.1 Approach for passenger trains

The approach contains three main steps which differ slightly between passenger and freight trains. For passenger trains these are:

1. Determine all train services that run through the scenario
2. Estimate the fleet size which is relevant for each train service determined in step one
3. Calculate the share of cost corresponding to the scenario

Once the scenario is set, all trains that run through the chosen scenario corridor have to be determined as they will have to be fitted with the new on-board technology if the functionality is no longer provided by the infrastructure. The length of each service line as well as the duration if one trip from the first stop to the last stop of the line can then be obtained from the railway undertaking providing each service (compare exemplary Table 9-1).

Table 9-1: Train Service Analysis

Train type	Service	Length (KM_T) in KM	Time per trip (h_T) in hours
Regional_Train_1	First_stop-Last_stop	50	1
Regional_Train_2	First_stop-Last_stop	100	2
Regional_Train_3	First_stop-Last_stop	80	2
High_Speed_Train_1	First_stop-Last_stop	300	2.5
…			

In a second step the fleet size necessary to run the total service has then been calculated taking into account the trains per hour per direction, the time per return trip including a turn-around time of $\frac{1}{6}th$ of the trip time (ratio of driving and rest time in Germany), a disposition reserve as well as a maintenance reserve [4]:

$$N_F = h_R \times N_P \times (1 + \frac{R_T}{100})$$

Where N_F = Number of trains per fleet for the service line, h_R = time per return trip including turn- around time, N_P = Number of trains per direction per hour, R_T = Total train reserve

With

$$h_R = 2h_T \times \left(1 + \frac{1}{6}\right) \text{ and } R_T = R_{Maintenance} + R_{Disposition}$$

Where h_R = time per return trip h_T = time per trip, R_T = Total train reserve, $R_{Maintenance}$ = maintenance reserve, $R_{Disposition}$ = disposition reserve

9.2.3.2 Approach for freight trains

While for passenger trains these data are available as public data from the train operators, cities and regions. For the freight trains however, these numbers are not available therefore the approach differs slightly from that for passenger trains.

For freight trains the approach is as follows:

1. Determine the average number of freight trains per hour that run through the scenario
2. Estimate the number of locomotives and wagons necessary to operate the programme determined in step one
3. Calculate the share of cost corresponding to the scenario.

For high density corridors, open source data for average freight train numbers exist. Especially in the context of noise mitigation measures or infrastructure action plans these data are collected and published as open source data.

To determine the fleet size for the freight trains, two calculations have to be done as the time per trip for the locomotive is shorter compared to that of the wagons. This is due to the fact, that the wagons need an additional amount of time for loading and unloading procedures in the terminals.

The number of locomotives can be determines by multiplying the average number of freight trains per hour with the duration per trip and a maintenance reserve. In order to get a value for the trip duration, the length of the trip as well as the average speed for wagons and locomotive has to be obtained. As freight train data are not publicly available, average values are used. The average kilometre per trip for the calculation is available from most railway undertakings for domestic transport; cross-border trips however can be longer.

Average values for the yearly kilometres of freight wagon and locomotives can be obtained from railway undertakings as well. These yearly kilometres can then be divided by 365 days and 24 hours to get an average speed value. With these assumptions the fleet size of locomotive and wagons can then be calculated as follows:

$$N_{FL} = 2 \times h_{TL} \times N_P \times (1 + \frac{R_{Maintenance}}{100})$$

Where N_{FL} = Number of locomotives per fleet for the service line, h_{TL} = time per trip in h for the locomotive, N_P = Number of trains per direction per hour, RMaintenance = Maintenance reserve

With

$$h_{TL} = \frac{KM_T \times 365 \times 24}{KM_{LY}}$$

Where h_{TL} = time per trip in h for the locomotive, KM_T = average kilometre per trip, KM_{LY} = average yearly kilometre of a locomotive

And the number of wagons respectively with the following equation:

$$N_{FW} = 2 \times h_{TW} \times N_P \times (1 + \frac{R_{Maintenance}}{100})$$

Where N_{FW} = Number of wagons per fleet for the service line, h_{TW} = time per trip in h for the wagons, N_P = Number of trains per direction per hour, $R_{Maintenance}$ = Maintenance reserve

With

$$h_{TW} = \frac{KM_T \times 365 \times 24}{KM_{WY}}$$

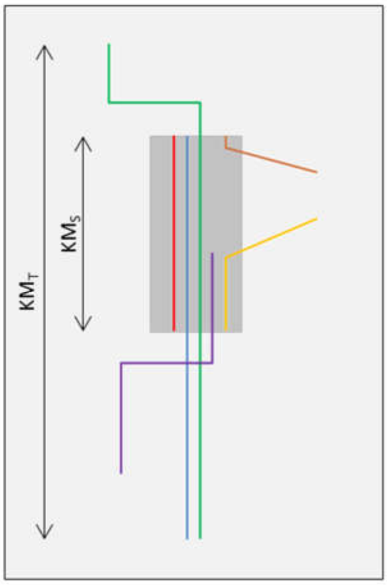
Where h_{TW} = time per trip in h for the wagons, KM_T = average kilometre per trip, KM_{WY} = average yearly kilometre of a wagon

9.2.3.3 Share of cost for passenger and freight trains

Under the assumption, that not only the investigated scenario will be retrofitted but the whole network, in the last step the ratio of the scenario km and the total kilometre of each service can be used to determine the share of cost of retrofitting the trains which can be compared to that of retrofitting the infrastructure as has been visualised exemplary in Figure 9-2.

$$C_S = \frac{KM_S}{KM_T} \times 100$$

Where C_S = Share of cost relevant for the scenario, KM_S = Service kilometre within the scenario, KM_T = Total service kilometre



Service	C_S
Scenario (red)	100
High_Speed_Train_1 (blue)	30
Freight (green)	10
Regional_Train_1 (purple)	30
Regional_Train_2 (yellow)	15
Regional_Train_3 (orange)	5

Figure 9-2: Share of Cost - movable assets

The number of passenger trains as well as freight trains determined with the described approach can now be multiplied with the cost for retrofitting each type of train as well as the cost share (C_S).

9.3 Conclusion

The approach described above has been developed within X2Rail-2 WP4 as part of the Cost-Benefit Analysis to asses effects of shifting the train integrity functionality from the infrastructure onto the train. The approach is based on approximation when detailed numbers of passenger and freight trains are not available. It is therefore not an exact representation of the real situation. It can however be adapted to the comparison of other functionalities as well. In all cases a detailed description of all assumption taken when determining the input values is mandatory for the reader to be able to interpret the results correctly.

The Methodology is only part of the CBA to determine the change in life cycle cost of the infrastructure elements and compare these to the shift of the functionality onto the train. Additional benefits that are not primarily cost related are not captured in this approach but are performed as part of the CBA in the X2Rail-2 project as well.

9.4 References

[1] "X2R2 D4.1 Train Integrity Concept and Functional Requirements Specifications, 2019.".
[2] European Comission, "Guide to Cost-Benefit analysis of investment Projects," Luxembourg, 2015.
[3] J. Nellthorp, "The principles behind transport appraisal," in the Routledge Handbook of Transport Economics, 2017, pp. 176-208.
[4] J. Anderson, "Calculation of performance and fleet size in transit systems," Journal of Advanced Transportation, Volume 16, Issue 3, 1982.

9.5 Author

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