Noise Assessment of Railway Innovations

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Keywords: railway innovations; noise assessment; KPI

1. Introduction

Within the European rail research and innovation initiative Shift2Rail there are several projects aiming to strengthen the European railway as a key element for sustainable mobility. Besides research and innovation projects for numerous technical developments, there are also researchers analysing on a system level the different aspects of the railway system evolvement, so-called Cross-Cutting-Activities (CCA), such as standardisation, human capital or energy consumption. Within the projects FINE1 (**F**uture **I**mprovements for **E**nergy and **N**oise) and IMPACT-2 (**I**ndicator **M**onitoring for a new railway **PA**radigm in seamlessly integrated **C**ross modal **T**ransport chains), experts aim to assess the effects of innovations developed within the Shift2Rail initiative towards noise emissions and the Key Performance Indicators (KPIs) Life-Cycle-Cost (LCC), Punctuality and Capacity (Shift2Rail, 2015). In the following the approach to integrate those two fields of research shall be described.

2. Combining two research fields in railway

2.1. Setting of noise assessment

The FINE1 project activities are supporting the innovation process within the Shift2Rail Technical Demonstrators (TDs) by providing methodology and know-how to enable the development of low noise solutions as well as to assess the improved noise performance on a system level including both vehicle and track (FINE1, 2017).

The reason for this analysis is that interactions between the Shift2Rail Innovation Programmes are of major importance since technological developments in one part of the rail system may lead to changes in performance or even create barriers in another part. In addition, the noise and energy performance of all the sub-systems together need to be assessed to define priorities that could not be reached with an analysis based only on an isolated part of a sub-system.

For the interior noise (including car body vibrations or structure borne noise), the levels, as well as the character of the noise, have major importance for passengers´ comfort of a rail journey. The exterior noise is important from an environmental point of view and is pushed both by politics (e.g. “TSI Noise” (EU Commission, 2014)) and society (cf. Burroughs, 2018). The reduction of exterior noise for railways is also highly recommended in the latest WHO´s “Environmental Noise Guidelines for the European Region” (2018), what underlines the importance of the topic. The Guidelines include a review of evidence on the health effects of environmental noise to incorporate significant research carried out in the last years including e.g. sleep disturbances as well as cardiovascular diseases. The main purpose of these guidelines is to provide recommendations for protecting human health from exposure to environmental noise originating from various sources such as railways for transportation.

The impact of improvements for both interior and exterior noise is further analysed within another Shift2Rail project, IMPACT-2.

The IMPACT-2 project is covering a number of overall aspects of the railway system, among others the quantitative assessment of the innovations developed in Shift2Rail against the KPIs: LCC, Punctuality and Capacity (cf. IMPACT-1, 2018b). A team of experts from industry, railway undertakings, infrastructure managers and research institutes across Europe aims to set up a KPI model. The model compares current railway system scenarios with future railway system scenarios, where all innovations developed within Shift2Rail are implemented and running (cf. IMPACT-1, 2018a). Additionally an “attractiveness model” is being developed with the purpose to quantify improvements in the attractiveness of the mode for the customer (Hainz et al., 2017). Both the results of the KPI model as well as those of the attractiveness model will finally be included within a mode choice model to estimate the actual “shift *to* rail”, which can be expected by the research and innovation results of the Shift2Rail initiative.

2.2. Research Approach

Besides the technical innovations of Shift2Rail, the KPI and the attractiveness models also aim to include those results of the other Cross-Cutting-Activities, which have an influence on LCC, Punctuality or Capacity or the attractiveness of the railway system. Therefore, improvements concerning noise, which are handled within FINE1, are covered as well. For this purpose three steps have been fulfilled:

- Topics concerning noise, which might have an effect on the KPIs or attractiveness, have been identified,
- Their connection to the KPIs and attractiveness has been analysed,
- It was assessed how to implement them in the models.

In the following, the four identified topics are further examined. Figure 1 is giving an overview of the content.

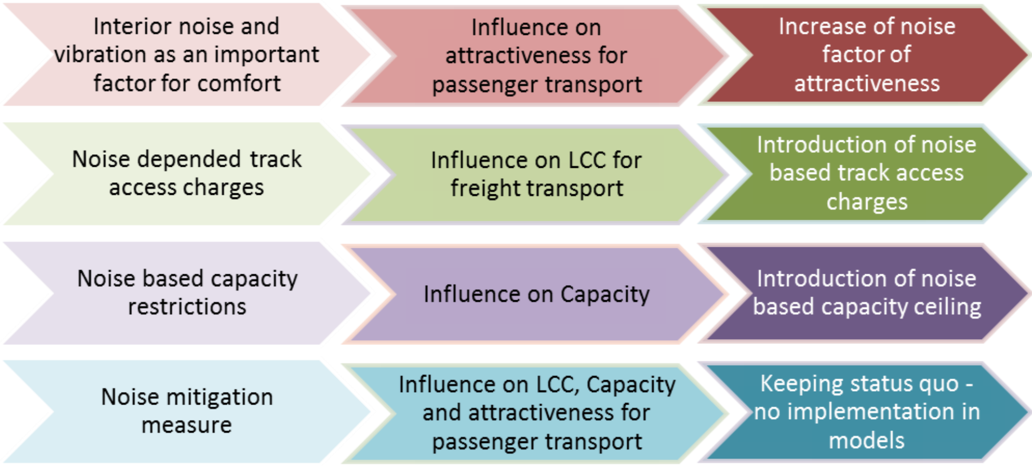

Figure 1: Noise topics for potential evaluation within LCC, Capacity, Punctuality and attractiveness

<u>Interior noise and vibration</u>

The first topic identified is interior noise and vibration (structure borne noise) influencing the comfort in passenger transport. While the effect of noise or vibration on the comfort of the journey during a train ride is easily comprehensible, the parts of the railway system causing noise or vibrations in the vehicle interior are diverse. Not only can the noise be caused by components of the vehicle or the vehicle design in general, but also by the layout of the infrastructure, the interaction of wheels and track or other parts of the railway system. Additionally, the cause will rely on maintenance conditions, speed and other operational factors. Therefore, determining changes in interior noise and vibration caused by changes in technological components is a challenging task.

Since interior noise and vibration do have a direct influence on the comfort of the train ride, this aspect is considered when developing new innovations for the railway. Even if the comfort of a train ride can hardly be measured in terms of cost, capacity or punctuality, which are classical KPIs for railway performance, interior noise and vibration must still be considered, when evaluating the attractiveness of a train journey.

Thus, the reduction of interior noise and vibration due to the innovations developed within Shift2Rail are transferred into a change of the noise related part of the attractiveness model. This means that, when the noise related part of the attractiveness model is improved in comparison to the status quo, the overall attractiveness of a train ride is improved. The magnitude of this improvement is dependent on the importance interior noise and vibration has for the customers. This differs from the type of journey hence the effect of noise reduction on a high speed train can be higher than on an urban train assuming interior noise and vibration is more important for customers on a long journey. The importance of interior noise and vibration on attractiveness for customers dependent on the different types of journeys is hereby backed by data from surveys and internal data from railway operators. The improved attractiveness overall, including the improvement of interior noise and vibration, will finally be assessed through a mode choice model and thereby an estimation if a shift from other modes such as cars towards railway will be possible.

Noise depended track access charges

The second topic is related to differentiated track access charges where a direct influence is identified. In contrast to the interior noise and vibration, noise depended track access charges do focus on exterior noise and environmental aspects. As the WHO Report from 2009 is showing, noise pollution from trains is a very important topic, not only to raise acceptance for rail transport within the public but also for the health of residents. A growing number of European Infrastructure Managers do implement noise-based track access charges (NDTAC[1]) to encourage the change to quieter trains and compensate the external costs of noise pollution (UIC Project 'Bearable limits and emission ceilings', 2011).

This aspect is mainly relevant to freight trains. By taking this noise-based track access charges into account when evaluating the Life-Cycle-Cost of the railway system, decreasing noise emissions do have a direct influence on those LCC.

As simple as this direct connection between noise depended track access charges seems, the differentiation of different aspects of cost for a railway is challenging by itself. There are different parts of the system that could be considered. First of all for railways, as for most mobility offers, there is the issue that a clear differentiation between a business point of view and an economic point of view from the society is not possible. As noise pollution would usually be classified as an economic topic, meaning that it would concern mainly society in comparison to single businesses, whereas track access charges are on the contrary a business aspect. For the railway system there are different stakeholders, which have costs and also charge other stakeholders. To stick to the terms of track access charges, track access charges are charged by Infrastructure Manager to Railway Undertakings. Track access charges usually should cover the investment cost and the maintenance of the infrastructure, but investments in railway infrastructure are often subsidised by governments and the example of noise depended track access charges shows that also other costs than investments and maintenance can be considered. Other stakeholders are for example suppliers or passengers / freight loaders. Between every stakeholder there are usually profit margins included or as mentioned government subsidies could have an influence. In addition these interrelations can differ significantly within Europe. Therefore, it is not the inclusion of noise depended track access charges into the KPI LCC that is the most challenging part, but instead to define a proper LCC definition for the European railway system and its components. As for noise depended track access charges they will be considered as being a representation of external costs for the railway system because of noise pollution and therefore being included as one part of the LCC calculations.

Noise based capacity restrictions

The third topic concerning noise, which might have an effect on the KPIs or attractiveness, is on the introduction of noise emissions ceilings. In some European countries, noisy trains are not only targeted by extra charges, but there is also a limitation of noisy trains in certain areas during a dedicated period of time, similar as it is known from airport operation during night time (UIC Project 'Bearable limits and emission ceilings', 2011). Two ways to limit noise pollution by limiting traffic, which are broadly discussed in public, are the reduction of speed especially in urban or suburban areas and night bans especially for freight trains (Jäcker-Cüppers, M., 2016). Of course, those could be actions to reduce noise from trains, but in the sense of encouraging rail transport as a sustainable form of mobility, simple limiting traffic without incentive for the railway branch to improve their noise emission values would not be expedient. Particularly in the networks shared by

[1] Noise differentiated track access charges (NDTAC)

passengers and freight in almost every part of Europe, speed limits or night bans would have an immense impact on route capacity and would thus directly conflict with the objectives of further developing and promoting rail transport. Therefore, the Netherlands can be named as a best practice example for a third way (UIC Project 'Bearable limits and emission ceilings', 2011). By introducing noise ceilings by mapped lines and only allowing so many trains until the ceiling is reached, the operators have an incentive to reduce the noisy trains to be allowed to run more trains on the line. Those ceilings can further be lowered during the years and hence the incentive to develop noise reducing technologies being refreshed.

Noise emissions ceilings have a direct impact on Capacity, similar to noise depended track access charges having direct influence on LCC.

By assuming a railway system with such noise-based capacity ceilings as a basis, a decrease of noise emission can also lead to a possibility of increasing the maximum capacity on these restricted lines. A few decibels reduction at the train / track source can allow an important increase of traffic in cases where capacity is limited by noise ceilings.

Noise mitigation measure and weight.

The last topic discussed is related to the weight of a railway vehicle. A reduction of weight can have positive effects on LCC, Capacity or attractiveness by reducing e.g. the wear and tear of the tracks and therefore their maintenance cost or by reducing the energy consumption and hereby the energy cost and CO2 emission or by enabling an increase of payload or allow more passengers or dedicate a higher share of the vehicle weight on e.g. information and entertainment equipment.

As much as a reduction in weight can have positive aspects, it can also harm the noise balance of the vehicle. For example weight is needed to have a high transmission loss of the floor to hinder the noise to enter through to the passenger compartment from the wheel and the rail sources underneath. Therefore, one of the goals of the noise activities for Shift2Rail innovations is to enable a weight decrease for vehicles without the negative side effect of increasing the noise.

For the evaluation of the railway innovations this means that the effects of weight reduction on Capacity, LCC and attractiveness can fully be taken into account positively, because of the potential elimination of the possible negative effects by noise.

2.3. Relevance of topic and discussion on results

Proper assessment of technologies for noise mitigation and their cost effectiveness is a very important topic in Europe.

The European Commission and numerous European national governments have committed themselves to railway transport as being a key element for a sustainable future of mobility (cf. EU Commission, 2009). The European railway net is widely operated via electrification, at least on the most frequent lines (cf. EU Commission, 2016), and therefore the sustainability of railway transport is not only caused by its inherent mass transport effect, but also raised by greening the energy supply in Europe.

Therefore, the acceptance of rail transport among the population is crucial, not only to use the existing rail transport offers, but also to enable a shift from less sustainable transport forms to rail transport. Noise emission by traffic and in some areas especially by railways is a continuously present topic in public. So the reduction of noise emissions by rail transport is a requirement to enable the shift to rail.

However the estimation of noise reductions by new technologies is often not an easy task, but as described desirable. Here the attempt to translate the results of noise reduction into KPIs can contribute to raising awareness of the importance of noise abatement already in an early development state of technologies.

Incentives and restrictions based on noise pollutions of trains have been introduced by governments as a trigger for noise friendly innovations, as described in an example below.

There is an important noise mitigation effect for existing freight wagons by using breaking the wheels with composite-brake blocks (CBB) instead of brake blocks made from cast iron (CI) (cf. Figure 2).

Composite brake blocks keep the surface of the wheels smoother and thereby less noise is created. As depicted in Figure 2 below it is shown in measurements of a large number of wagons in Switzerland that the average pass by noise is reduced from 85 dB (A) to 73 dB (A), that is a very impressive 12 dB (A) reduction.

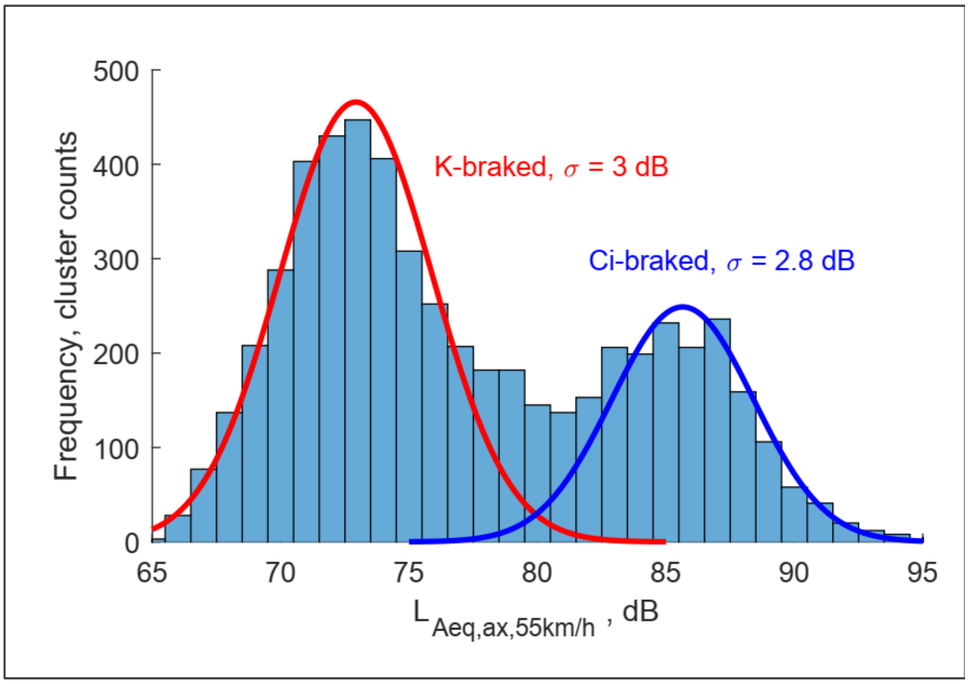

Figure 2: Level variation of freight train axle clusters (Pieren, Lauper and Heutschi, 2018)

Unfortunately, the renewing rate of freight wagons is usually very low (because of the long life cycle of freight wagons, 40 years and more) and it would take several years for the noise mitigation effect to unfold its full potential, if only used for new wagons and not started with retrofitting old wagons with the brake blocks of the new composite materials (EU Commission, 2013). This effect is illustrated in Figure 3 where one can see for example that if 45 % of all wagons on a railway line are replaced with low noise wagons (being 7 dB less noisy) the total average noise reduction experienced e.g. by the people living close to the line is only 2dB. Hence, to get a full effect a high percentage of the wagons need to be low noise.

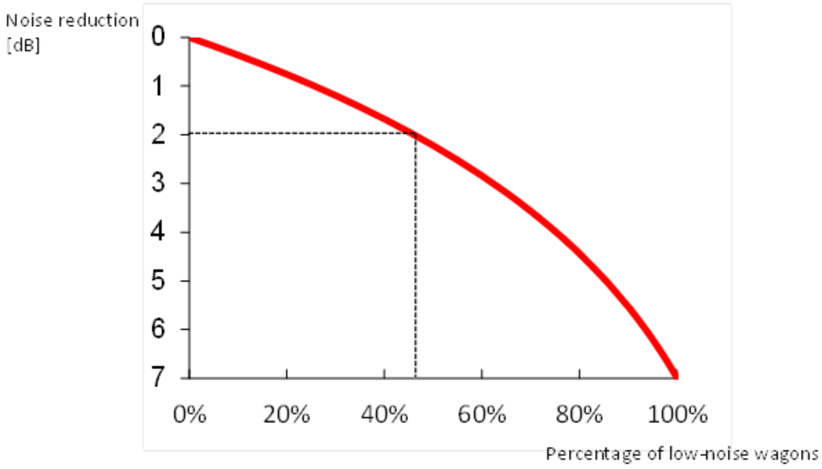

Figure 3: Noise reduction depending on the degree of conversion with low-noise-wagons (example: 45% quiet vehicles lead to a noise reduction of 2 dB).

Therefore, several states in central Europe started programs to encourage the retrofitting of their old freight wagon fleet with the new brake block technology. Countries like Switzerland and Germany started with actions to ban wagons with old CI brake blocks from their network. Switzerland will have a national ban of noisy CI wagons with the beginning of next year, 2020, in Germany a similar ban is planned for End of 2020 (Deutscher Bundestag, 2017).

As such, national ban is in principle against the agreed European transport politics with an open interoperable market and non-discriminatory access. However, the European Commission started with similar actions to trigger the modernisation of freight wagons. In the past years a Working Party started to revise the TSI Noise (EU Commission, 2014) so that after a transition period only "silent", that means TSI Noise compliant freight wagons, will be in operation. This limited revision of TSI Noise does foresee a ban of "noisy" freight wagons from End of 2024 on, for all so-called quieter routes. Quieter routes are defined as sections of the railway network, where only TSI Noise compliant freight wagons are allowed to operate. Thereby quieter routes are defined for railway lines with more than twelve freight trains per night so that the most important lines for international and long-distance trains will no longer be open for Non-TSI compliant wagons from the end of 2024 and on (EU Commission, 2019). This is the first time that a TSI regulation has retroactive access to existing wagons or infrastructure.

Nevertheless, to create and decide actions such as the ban of freight wagons with a specific type of brakes, decision-makers must understand the benefits of the change of technologies. Therefore, the assessment of noise effects for railway innovations is an important part of enabling the shift to sustainable mobility.

3. Conclusion

The evaluation of impacts on the railway system as well as noise and vibration calculations is a complex task. The proposed approach in this paper to include noise reduction in classical KPIs is bound to have restrictions and to be based on special assumptions. For example, the relation between noise reduction and passenger comfort is a whole research field by itself not only taking the levels but also the sound quality into account. Either way, the reduction of noise and vibration is an important topic for railway systems to have acceptance among the citizens in Europe for this sustainable mobility mode. Therefore the reflection of this importance in the evaluation of classical KPIs such as LCC or Capacity is important to finally enable the improvement of public transport in its holistic aspects.

Disclaimer
The authors express their acknowledgement to the Shift2Rail Joint Undertaking for financing the projects FINE1 (GA 730818) and IMPACT-2 (GA 777513) related to the work presented here. This contribution reflects the views of the authors and does not necessarily reflect the views or policy of the Shift2Rail Joint Undertaking or the European Commission.

References

Burroughs, D. (2018). The quiet revolution in noise abatement. In: IRJ. Available at https://www.railjournal.com/in_depth/the-quiet-revolution-in-noise-abatement [15.05.2019].

Deutscher Bundestag (2017). Bundestag verbietet den Einsatz lauter Güterwagen. Available at https://www.bundestag.de/dokumente/textarchiv/2017/kw13-de-schienenlaermschutzgesetz-499920 [16.05.2019].

EU Commission (2009). A sustainable future for transport — Towards an integrated, technology-led and user-friendly system. Available at https://ec.europa.eu/transport/sites/transport/files/media/publications/doc/2009_future_of_transport_en.pdf [16.05.2019].

EU Commission (2013). Effective reduction of noise generated by rail freight wagons in the European Union 2013, Roadmap of DG Move. Available at https://ec.europa.eu/transport/sites/transport/files/modes/rail/studies/doc/2014-05-rail-noise-ia-study.pdf [16.05.2019].

EU Commission (2014). COMMISSION REGULATION (EU) No 1304/2014. Available at https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32014R1304 [15.05.2019].

EU Commission (2016). Energy Union and innovation – Electrified railway lines. Available at https://ec.europa.eu/transport/facts-fundings/scoreboard/compare/energy-union-innovation/share-electrified-railway_en [16.05.2019].

EU Commission (2019). Commission Implementing Regulation amending Regulation (EU) No 1304/2014 as regards application of the technical specification for interoperability relating to the subsystem 'rolling stock — noise' to the existing freight wagons. Available at http://ec.europa.eu/transparency/regcomitology/index.cfm?do=search.documentdetail&dos_id=0&ds_id=59069&version=6 [16.05.2019].

FINE1 (2017). D5.1- List of TDs influencing the N&V performance of the system. Available at https://projects.shift2rail.org/s2r_ipcc_n.aspx?p=FINE%201 [15.05.2019].

Hainz, S., Vannier, E., Meyer zu Hoerste, M.; Kristoffersson, I. (2018). Passenger Demand in a Technical World. Presented at the Rail Transport Demand Management RTDM 2018.

IMPACT-1 (2018a). D4.1 Reference Scenario. Available at https://projects.shift2rail.org/s2r_ipcc_n.aspx?p=IMPACT-1 [available soon].

IMPACT-1 (2018b). D4.2 Subsystem structure and Sublevel KPIs. Available at https://projects.shift2rail.org/s2r_ipcc_n.aspx?p=IMPACT-1 [available soon].

Jäcker-Cüppers, M. (2016). Railway Noise Control in Germany - a Success Story and an Example for Europe. Presented at the Internoise 2016.

Pieren, R., Lauper, D., Heutschi, K. (2018). Demonstrator for rail vehicle pass-by events. Presented at the Euronoise 2018.

Shift2Rail. (2015). Shift2Rail Strategic Master Plan. Available at https://ec.europa.eu/transport/sites/transport/files/modes/rail/doc/2015-03-31-decisionn4-2015-adoption-s2r-masterplan.pdf [15.05.2019].

UIC Project 'Bearable limits and emission ceilings' (2011). Exploring bearable noise limits and emission ceilings for the railways. Part I: National and European legislation and analysis of different noise limit systems. Available at https://uic.org/IMG/pdf/p250_bearable_noise_limits_part_i_final.pdf [15.05.2019].

WHO, World Health Organisation (2009). Night Noise Guidelines for Europe. WHO Regional Office for Europe, ISBN:978 92 890 4173 7. Available at http://www.euro.who.int/__data/assets/pdf_file/0017/43316/E92845.pdf [15.05.2019].

WHO, World Health Organisation (2018). Environmental Noise Guidelines for the European Region. WHO Regional Office for Europe, ISBN: 978 92 890 5356 3. Available at http://www.euro.who.int/__data/assets/pdf_file/0008/383921/noise-guidelines-eng.pdf?ua=1 [17.05.2019].