EUROPEAN UNION AGENCY FOR RAILWAYS

Making the railway system work better for society.

Full Impact Assessment

Revision of the Noise TSI: Application of NOI TSI requirements to existing freight wagons

	Elaborated by	*Validated by*	*Approved by*
Name	EKSLER Vojtech SCHROEDER Martin	GHERGHINESCU Oana PIRON Olivier	GIGANTINO Anna DOPPELBAUER Josef
Position	Project officers	Heads of sector	Head of Unit / Executive Director
Date	18/04/2018	30/04/2018	30/04/2018
Signature		[signatures]	[signatures]

Contents

1. Context and problem definition

1.1. Problem and problem drivers	According to the 2014 Eurobarometer survey, 29 % of EU-28 citizens are often or very often disturbed by traffic noise; of these, 13 % are affected by rail noise[1]. Noise from **running freight wagons** is considered by European railway experts as **the most important contributor to railway noise problems**. The magnitude of the noise problem is the function of the density of population in the vicinity of the railway lines, and to a lesser degree, of the frequency of trains. The **exposure** of European citizens to harmful noise levels is uneven and vary considerably among the Member States and even within single Member State. This is due to different population density, rail network planning and development, local legislation and other drivers. The **perception** of noise, as one of transport externalities, also varies considerably among Member States. Despite a common framework introduced by the Environmental Noise Directive (END), the level of attention given to railway noise by government and rail infrastructure managers is likely to continue to vary. The railway noise problem is concentrated in central Europe, where the majority of the affected citizens live and the volume of rail freight transport is highest (primarily Germany, Italy and Switzerland, but traffic density is high also in Poland, Austria, the Netherlands and France, and noise mapping indicates that significant population is affected in Belgium and Luxembourg). Although the costs to tackle railway noise are pretty similar across the EU, the **public resources available** to tackle railway noise are not the same. This is due to both different economic performance and different policies. The European Environment Agency (EEA) estimated in 2017 that **railways are the second most dominant source of environmental noise in Europe**, with nearly 14 million people affected[2,3]. The noise exposures have been linked to a range of non-auditory health effects including annoyance, sleep disturbance, cardiovascular disease and impairment of cognitive performance in children[4]. The root problem of rail noise is identified with the braking technology used (cast iron brake blocks), which affects the wheels' surface and increases the roughness of the rail, resulting in more rolling noise. Rail freight wagons equipped with cast iron brake blocks currently represent about 75 % of all the European freight wagon fleet.

[1] Special Eurobarometer, Nr.420 Passenger Rights, EC 2014"

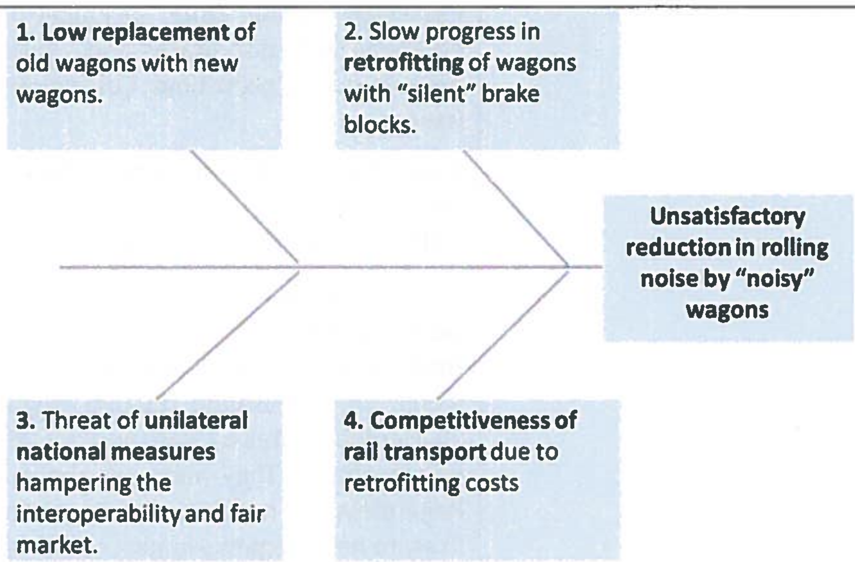
[2] The latest reported data under END measurement as of August 2013, shows 7 million people exposed to levels above 55dB L_{DEN}. (Noise in Europe, EEA, 2014)

[3] Managing exposure to noise in Europe, EEA Briefing 01/2017, EEA 2017

[4] Special Issue "WHO Noise and Health Evidence Reviews", International Journal of Environmental Research and Public Health (ISSN 1660-4601), 2018

	Passenger rolling stock including high speed trains, are typically equipped with disc brakes and, unlike the freight wagons, they rarely operate during night time. Consequently they are considered less of an issue. Rough tracks also contribute to the rolling noise and track maintenance (acoustic grinding) has been used to address it. Yet, it is costly, disrupts traffic and has a limited impact. Due to existing and growing public concern about railway noise, Germany and Switzerland plan to **restrict operation of noisy wagons on their national railway network from 2020 onwards**. These restrictions would concern around 180,000 freight wagons registered in any of EU-28 Member States by 2020 and operated in these countries that need to be retrofitted. They make up about 25 % of all wagons by that time. Regardless the nature and extent of the planned restrictions, they are likely to have negative impact on operating and financial conditions of all railway undertakings operating the freight wagons in the two countries. Retrofitting of existing wagons with silent brake blocks would immediately and directly provide benefits to citizens (noise reduction), but at the same time it brings along **considerable costs to the railway industry, affecting the level playing field** when it comes to competition with road transport and potentially leading to a reduction of rail freight traffic in the EU. This would undermine EU policy goals, notably in carbon emission area. The current **composition of the wagon fleet** used in different MSs in respect to their noise generation vary considerably, ranging from practically zero silent wagons operated in some MSs to almost 100 % of operated wagons being silent in other MSs. This implies significant differences in the retrofitting and renewal costs of the wagon fleet across the EU. In the absence of the application of suitable and sustainable rail noise mitigation measures, **operating restrictions** such as night bans or speed limitations, may be introduced. These would limit line capacity and negatively affect rail transport competitiveness, thus jeopardizing policy goals in the area of transport and climate change. Furthermore, the free movement of goods in the European Union can be endangered. Specifically, the measures planned for introduction in Switzerland and Germany (legislative measures in Switzerland and Germany) may represent a threat to seamless and efficient cross border operation of freight trains in Europe and make it altogether most costly and thus less competitive. This also jeopardizes the EU White Paper[5] policy goals of shifting freight to rail. **Main problem addressed by the current IA**: Unsatisfactory approach (or setting) at EU level for reducing rolling noise by existing "noisy" wagons The problem and problem drivers are displayed in the diagram below.

[5] COM/(2011) 144, White Paper, Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system



1.2. Main assumptions

This impact assessment focuses on one particular measure to tackle railway noise: the **retrofitting of freight wagons brake blocks**. A number of past assessments determined that this is the most cost efficient measure to tackle railway noise (e.g. research project STAIRRS[6] and resulting 1998 UIC noise Action Plan[7]). An alternative measure: construction of railway side noise barriers is not analysed in this impact assessment, as it would constitute a different policy scenario.

The **interaction between wheels and rails causing the rolling noise** is the most predominant source of railway noise. Rolling noise depends on both the roughness of the wheel surface and the roughness of tracks it is rolling on. Wheel roughness is dependent on the braking technology, most damaging being the cast iron brake blocks. Alternative braking technologies in the form of composite brake blocks or disc brakes cause less or no increase of the roughness of wheel surface and therefore the rolling noise level is relatively lower. The direct effect of brake blocks replacement accompanying by wheels reprofiling is a rolling noise reduction of 8 dB.

Following the entry into force of the current NOI TSI requirements in 2007, **new wagons are usually equipped with silent braking technology** (composite brake blocks or disc brakes). Unless retrofitted, the wagons put into operation before that date continue to be equipped by "noisy" brake blocks as they have economic advantages to owners and keepers, arising from lower installation and brake/wheel maintenance costs.

Since the 1,520 mm network was exempted from the application of TSI and all options under this IA are realized through amendments to NOI TSI, the **1,520 mm network of Estonia, Latvia and Lithuania are not considered in this IA**. At the same time, the railway network of Norway and Switzerland are included, the former falling under the TSI application scope and the latter due to operating impacts on other countries.

[6] STAIRRS Final technical report, STR40TR181203ERRI, project ref: B99/99/S12.107978- B66131122

[7] Environmental Noise Directive Development of section plans for railways, UIC, 2008

	The **impacts of NDTAC schemes are not considered in the IA**, as they are out of scope of the discussed regulatory measure (revision of NOI TSI). The **period of analysis** is 2017-2036 (20 years), being a standard time frame for this type of IA[8].
1.3. Stakeholders affected	**Citizens**, in particular those living in the vicinity of railway lines are the most affected (health and property value) stakeholder group and they are likely to benefit from wagon brake blocks retrofitting. **Railway Undertakings and Railway vehicle keepers** are directly affected as they would have to bear the costs of any mandatory retrofitting of "noisy" brake blocks with "silent" brake blocks. The **European Commission alongside with Member States** acting as legislators, and as potential providers of financial support to the sector are also concerned. **Entities in Charge of Maintenance**, brake blocks manufacturers and maintenance workshops are affected as well as they would need to provide additional capacity to assure retrofitting and to accommodate the increased maintenance cycle. The following assessment of the importance of the problem as per stakeholder category was done using expert opinions in the Agency combined with comments from the Task Force (TF) and Working Party (WP) members.

Category of stakeholder	*Importance of the problem*
European citizens	4
Wagon keepers, RUs	5
EC and Member States	2
Manufacturers and ECMs	3

[scale 1(low) to 5 (high)]

1.4. Evidence and magnitude of the problem	**Railways are the second most dominant source of environmental noise in Europe**, with nearly seven million people exposed to levels above 55 dB L_{den} in 2012 considering people exposed both inside (agglomeration with more than 100,000 inhabitants) and outside urban areas (major railway lines with more than 30,000 train passages per year), as reported under END in August 2013. Estimation - based on calculated figures complementing current reported data to estimate the overall number of people exposed - increases this figure up to nearly 14 million people, doubling the current reported data, with more than 4 million people estimated to be exposed to major railways transport outside urban areas and 9.5 million people estimated to be exposed to railways transport noise inside urban areas. (In fact, the real figures are undoubtedly higher since the EEA's European noise mapping initiative concentrates on agglomerations with over

[8] Guide to cost-benefit analysis of investment projects, EC DG Regio, 2014

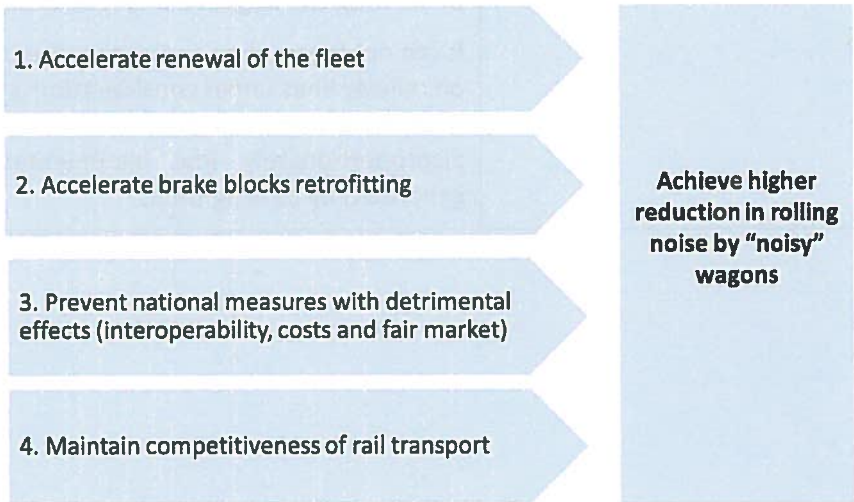
	100,000 inhabitants and on main railway lines with over 30,000 trains per year.). The **renewal of the freight wagon fleet in Europe** has been less than 1.5% per year since 2010, according to the data available to ERA. The **retrofitting** has so far been mostly limited to countries which provided public financial support. According to data collected by ERA in the framework of this impact assessment, only 68,000 wagons have been retrofitted with composite brake blocks by 2017. The retrofitting of freight wagons with composite brake blocs, lead to additional life cycle costs estimated at almost EUR 1,000 per year[8]. This increases the operational costs of rail freight transport by about 2 %. A **potential ban on noisy wagons in Germany and Switzerland** give cause for concern for the functioning of the internal market. Several rail freight corridors run through Switzerland, and if "noisy" wagons cannot operate there, this might impede intra EU transport and trade. The **retrofitting of brake blocks is costly** and increases the maintenance and operating costs, since the composite materials (K and LL-brake blocks) wear out quicker. A full impact assessment on rail freight noise reduction was carried out by COWI consultants for the European Commission in May 2014[9], which was further updated by the EC services[10]. It contains a comprehensive evidence of the magnitude of the rail noise problem in the EU and proposes ways forward. It confirms that the application of the NOI TSI requirements to existing freight wagons is the most effective and efficient solution for rail environmental noise reduction in the EU.
1.5. Baseline scenario	In the absence of specific measures at the level of Noise TSI, the situation will be characterised by the following: 1. **"Silent" wagons will continue to represent a minor share of the total fleet**, leading to a limited railway noise reduction with the EU even in the long term, given a very long lifespan of freight wagons (ranging from 40 years to virtually indefinite duration – if subject to regular proper maintenance) and limited dynamics in freight transport market needs. 2. **Limited retrofitting will happen**, mainly based on ongoing retrofitting programmes in Germany, Austria, France, Netherlands, and Czech Republic. The wagons planned for retrofitting and receiving public subsidy under the CEF I call covering the period 2014-2020 are also considered. 3. **It is assumed that all wagons operated in Switzerland will have to be "silent" as from 1.1.2022 and that government incentives in Germany will lead to an increase in the number of silent wagons**, with the number of silent wagons in 2022 being sufficient to assure operation of all trains on German network.

[9] COWI, Effective Reduction of Noise generated by Rail Freight Wagons in the European Union, May 2014

[10] EC SWD(2015) 300 final: Commission Staff Working Document: Rail freight noise reduction, December 2015

	4. The measures in Switzerland and Germany **may have an impact on retrofitting in other countries** (business-driven retrofitting), where the railway undertakings operated in those countries are expected to retrofit/renew relevant part of their fleet by the dates above. The estimation of the minimum fleet to be retrofitted in respect to their country of registration is done on a basis of known share of wagons operated internationally and estimated proportion of those used to run in the two countries above.
1.6. Subsidiarity and proportionality	While the effect of excessive noise can be considered as local, the same cannot be said for the source of the problem. Today, about 50 % of rail freight transport in the EU is international and this share is expected to further increase. This implies that a large number of wagons need to be run seamlessly across the borders. Any attempt to address rail noise at source needs to recognise this aspect. If Member States take **unilateral (national) measures** to limit traffic of noisy wagons on their national network, new barriers to interoperability will be created, negatively affecting the rail traffic on cross-border corridors. In the preparation of these possible unilateral measures, some Member States started a programme of subsidies to retrofit freight wagons operated on their territory, or registered in their countries. **EU action in the domain of rail noise reduction can strengthen the national policies and measures**, and would produce additional benefits on top of actions at Member State level. It may address concerns of possible discrimination of operators and of citizens. EU action could aim at **increasing the pace of the retrofitting** in order to obtain socio-economic benefits at an earlier stage, considering the otherwise low natural replacement rate of about 1.5% per year, while minimizing the negative financial impact on the railway sector. It can notably seek to assure that the proportion of "noisy" wagons used on railway lines under consideration is as low as possible, ideally nil. This is because a small proportion of "noisy wagons" in the fleet leads to disproportionately low incremental increase in noise reduction generated by passing trains.

2. Objectives

2.1. Strategic and specific objectives	**European Union Agency for Railways strategic objectives:** ☐ Promoting rail transport to enhance its market share ☒ Improving the efficiency and coherence of the railway legal framework ☒ Improve economic efficiency and societal benefits in railways **General objectives:** › *to increase quality of life and protect health of European citizens living close to railway lines (exposed to high noise sound pressure);* › *to support the development of rail transport and functioning of the single European rail area;* › *to achieve tangible reduction in noise generated by rail freight in mid-term.* **Specific objectives:** The following were determined in the response to the problems identified: › *to accelerate renewal of the fleet (and avoid overutilization of old rolling stock);* › *to accelerate brake blocks retrofitting with composite brake blocks;* › *to prevent national measures having detrimental effects on freight by rail and to ensure fair market/operating conditions for operators of new and older wagons and to avoid noise-triggered obstacles to interoperability.* › *to maintain the competitiveness of rail sector vis-à-vis other modes of transport* 
2.2. Link with Railway Indicators	No links with the railway indicators of the Agency. Links exist with EC White Paper Indicators on modal share of rail and road freight transport.

3. Options

3.1. List of options	**Baseline scenario (option 0)**: Scope of application of the NOI TSI remains limited to new wagons, taking into account operating restriction in Switzerland and fleet evolution in Germany stimulated by subsidies. **Option Ia**: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2022 **Option Ib**: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2025 **Option IIa**: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2022 where wagons not operated internationally are exempted until 1.1.2028 **Option IIb**: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2025 where wagons not operated internationally are exempted until 1.1.2030 **Option IIIa**: NOI TSI scope is extended to wagons using "silent" networks (= AT,DE,NL,CH) as from 1.1.2022. **Option IIIb**: NOI TSI scope is extended to wagons using "silent" networks (= AT,DE,NL,CH) as from 1.1.2025 and to all networks from 1.1.2030. **Option IVa**: NOI TSI scope is extended to wagons using "quieter routes" as from 1.1.2025* **Option IVb**: NOI TSI scope is extended to wagons using "quieter routes" as from 1.1.2025 and to all routes from 1.1.2030 The implementation year 2022 corresponds to the latest expected application of ban on noisy wagons in Switzerland and Germany (in the absence of a European wide accepted implementation strategy), while the implementation year 2025 corresponds to the preferred start of the Quieter routes implementation strategy. *Note that **Option IV** was retained by the Commission in its request to the Agency for revising the NOI TSI. See letter 'Request for recommendations to the Commission pursuant to Art. 5, par. 2 of the Interoperability Directive (EU) 2016/797', ref. MOVE/C.4/BC/tg, mandating the European Union Agency for Railways to propose a clause or clauses specifying the application of the TSI NOI to the existing freight wagons following the 'quieter routes' implementation strategy with a deadline of April 2018.* **) Implementation date of 08/12/2014 is proposed in practice aligning it with the yearly timetable change.*
3.2. Description of options	Under the Baseline scenarios (**Option 0**), no new regulatory requirements on existing wagons are introduced in the NOI TSI. Existing retrofitting stimulating measures (public subsidies) applied in different Member States and at the EU level (e.g. Connecting Europe Facility (CEF)), as well as noise-differentiated track access charges (NDTAC) are taken into account. The noise generated by wagons equipped with cast

iron brake blocks (noisy wagons) will diminish due to increased share of “silent” wagons.

Under **Option I**, all ”noisy” wagons will have to be transformed into “silent” by either retrofitting their brake blocks or by being decommissioned by a given year. The application dates correspond to an announced ban on noisy wagons in Germany and Switzerland and to preference application year for quieter routes established with the railway sector, respectively.

Under **Option II**, gradual application of the regulatory requirements on existing “noisy” wagons is foreseen. The “noisy” wagons could continue to be operated if they are exclusively operated on a network of one single member state. All “noisy” wagons will ultimately be banned from operating in the EU.

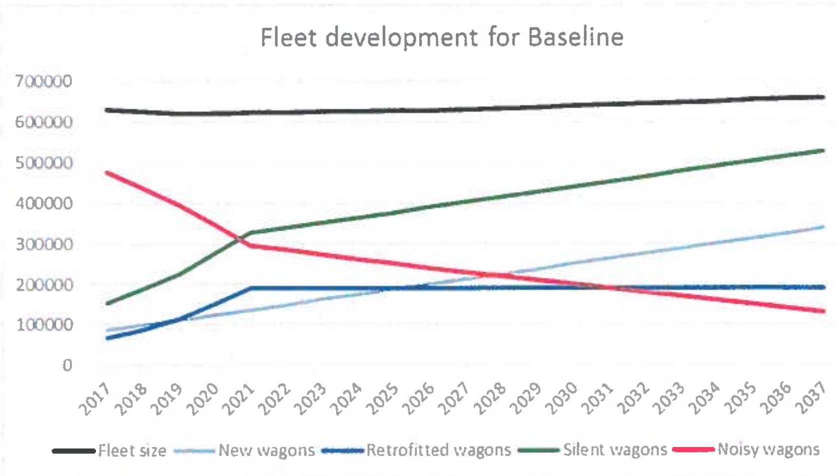
Under **Option III**, gradual application of the regulatory requirements on existing “noisy” wagons is foreseen. The “noisy” wagons could continue to be operated in those MSs which do not declare their networks as “silent”. An ultimate ban (flat application in all MSs) could be later imposed.

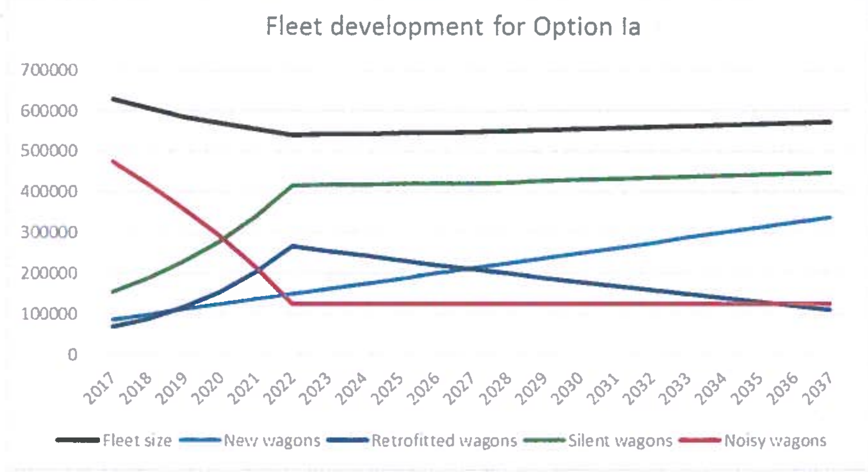
Note that legal service of the European Commission advised that this option *is not feasible (acceptable)* *from the regulatory point of view. It is however included in this IA for the sake of comparison with other options.*

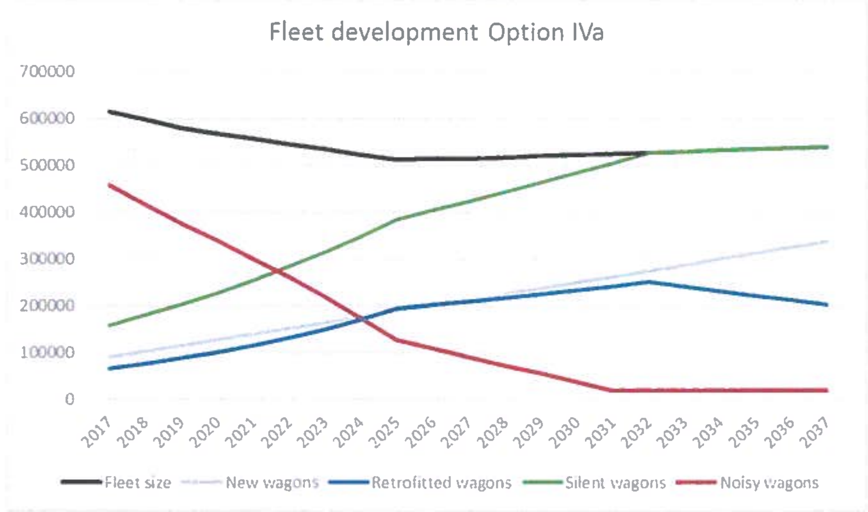
Under **Option IV**, gradual implementation of the regulatory requirements on existing “noisy” wagons is foreseen. The “noisy” wagons could continue to be operated on the parts of the railway networks, which were not determined to be “quieter”. An ultimate ban (flat application in all MSs on all railway lines) could be later imposed.

Note that according to the railway sector, the sub-options Ia, IIa and IIIa may not be practically feasible, or lead to additional extra costs, as they would require retrofitting of a large number of additional wagons by 2022, for which there may not be sufficient workshop capacity.

While the Annex I gives a more detailed description of the options, the series of graphs bellow provides an illustration of expected fleet developments for the baseline and the most relevant (sub-)options.



<table>
<tr><td></td><td>


</td></tr>
<tr><td>3.3. Uncertainties/risks</td><td>The development in wagon fleet constitute the main driver for the cost-benefit analysis in this IA.

The development in the wagon fleet for the baseline is driven by the response of different countries to German/Swiss policies and to the availability and extent of public support mechanisms for retrofitting.

Besides, the future development in the number of wagons for different options must be estimated, since no models currently exist for the estimation of wagons needs in relation to operational conditions. Assumptions have to be made in respect to the expected use of different types of wagons across the railway networks.</td></tr>
</table>

4. Impacts of the options

4.1. Impacts of the options (qualitative analysis)

Criteria/Option	*0*	$I_{a,b}$		$II_{a,b}$		$III_{a,b}$		$IV_{a,b}$	
Accelerate renewal of the fleet	1	2		4		4		4	
Accelerate brake blocks retrofitting	1	5	4	4	3	3	2	3	2
Prevent national measures, ensure fair market and interoperability	1	5		4		4		4	
Maintain competitiveness	5	1	2	3	4	4	5	5	4
Overall ***(rounded to 1 decimal)***	**2.0**	**3.3**	**3.3**	**3.8**	**3.8**	**3.8**	**3.8**	**4.0**	**3.5**

Note: 1-very low response to 5-very high response

The assessment above reflects the expert opinions at the Agency and comments received from the WP members.

Stakeholder effects matrix

RUs/Keepers	Positive impacts	Regulatory framework certainty, Homogenous requirements across the EU, Conditions for fair competitions.
	Negative impacts	Costs associated with brake blocks retrofitting (one-off and additional operational costs). Administrative and additional operating costs.
IMs	Positive impacts	Avoided construction of noise barriers.
	Negative impacts	Implementation of new regulatory requirements (data provision, monitoring, reporting, route planning).
Citizens	Positive impacts	Reduced environmental noise from rail transport.
	Negative impacts	Possible modal shift due to increased operational costs of rail freight transport.
Overall assessment	Positive impacts	+++
	Negative impacts	--

These effects apply to all options. The economic impacts on other stakeholders are relatively small, therefore they are not listed here. Among the impacts listed above, the costs associated with the retrofitting and the benefits from reduced railway noise are the two key impacts to be assessed in this impact assessment.

4.2. Impacts of the options (quantitative analysis)	General assumptions used in the quantitative analysis are listed below, additional information is available in Annex I. *Wagon fleet:* Average theoretical lifetime of a freight wagon is 40 years leading to a natural average annual renewal rate of 2.5 %. However, due to persisting economic environment of narrow profit margins in the railway sector, a 2 % annual renewal rate (corresponding to 50 years wagon lifetime) is assumed in this IA. The total freight wagon fleet as of 1.1.2017 is estimated to be 630,000 wagons, of which 500,000 are wagons equipped with monoblock wheels with a maximum speed of 100 km/h or less (s-wagons), 40,000 are wagons with a maximum speed of more than 100 km/h (ss wagons), and 95,000 are tyred-wheel wagons. The number of wagons that cannot be technically retrofitted (e.g. small diameter wheel wagons) or exempted from the NOI TSI requirements is assumed to be 13,000, which are directly deduced from total and not considered in the impact assessment (marginal noise effects due to limited use, speed). The total number of wagons is expected to diminish in case of an extension of the scope of NOI TSI noise emission requirements to existing wagons ("noisy wagons ban") to less than 500,000 wagons by the relevant ban year as a consequence of the rationalization and optimization of the fleet. An average theoretical wagon is considered to have the following characteristics: Annual mileage of 45,000 km and 4 axles on average. In the absence of detailed wagon use data, we assume that the number of wagons operating on the network of one country equals the number of wagons registered in that country. In case of the introduction of a ban on "noisy wagons" in a cluster of countries, the total number of "silent wagons" registered in other countries that are operated in "silent countries" is estimated from available data on international traffic volume per country[11]. *Retrofitting costs:* Two types of costs are considered for three different wagon types (see above): One-off installation costs and life-cycle maintenance costs. All known types of costs are considered (Material, Work, Disposal, Production costs, Transport costs) and the difference in costs for CI brake blocs and LL brake blocks calculated. For example, the costs assumed for the S-type wagon are: One-off costs: 0.039 €/km (1,756 €/wagon/year) and additional life-cycle costs: 0.022 €/km (970 €/wagon/year). The average maintenance intervals (brake blocks replacement, wheels reprofiling, wheelset replacement) have been determined as a result of consultations with different stakeholders.

[11] Fifth report on monitoring developments of the rail market, COM(2016) 780 final, EC 2016

	Administrative and logistics costs: It is assumed that the application of different implementation scenario leads to the additional administrative and logistics costs to manage dual fleet. They are, expressed per wagon run of a "noisy" wagon and assumed to amount to 8 €/wagon run (Option II + Option III) and 20 €/wagon run (Option IV). *Noise impacts:* It is assumed that a fully silent wagon fleet would correspond to the 8 dB noise reduction. A formula developed by COWI consultants and applied in an former impact assessment related to rail noise reduction measures is used to calculate the resulting noise reduction for a specific share of silent wagons in the total wagon fleet. The dB effects are translated into effects on the population exposure to noise, using information on the population exposure to noise in the 2012 Environmental Noise Directive (END) noise measurement. The monetization of noise impacts is done by estimating burden of disease (BOD) due to environmental noise. For the three types of diseases considered, the following disability weights taken from the WHO (2004)[12] are taken: 0.124 for cardiovascular diseases (corresponding to lower value of angina pectoris) and 0.03 for annoyance and for sleep disturbance respectively. Odd ratio for the incidence of the cardiovascular disease is 0.046 (Eurostat), whereas the percentage of fatal cases in case of an acute event is considered to be 0.051 (OECD). We assume that, in case of "quieter" routes implementation strategy, the value of noise reduction comes with 30 % from quieter routes and 70 % comes from all other routes. *Modal-shift effect:* The external costs of road transport are considerably higher 0.0334 €/tkm than external costs of rail transport 0.006 €/tkm (CE Delft 2014). We assume that the internal cost of rail freight transport is € 0.04 per tkm. The TALCC influence the total costs of rail freight transport by less than one per cent. Assuming a middle value of cross-price elasticity of 1.25, the TALCC of retrofitting triggers the shift of freight from rail to road of less than 1 %, i.e. less than one per cent of tonne kms carried out currently by rail would be carried out by road as a consequence of the increase in the operating cost in rail transport. *Costs and benefits estimation:* Discount rate of 4 % was applied to calculate the net present value (NPVs) in the B/C analysis for each option. *Wagon needs:* We assume that 35 % of wagons could be operated exclusively in one single MS, with all other wagons being "international". This leads to the

[12] Global burden of disease 2004 update: disability weights for diseases and conditions, WHO, 2004

need of 361,000 silent wagons, of which 140,000 additionally retrofitted (Option IIa).

We assume that 50 % of wagons registered in countries with "noisy networks" would need to become "silent", in order to operate in countries with "silent networks". This leads to 170,000 silent wagons in these countries (of which 77,000 additionally retrofitted) (Option IIIa).

We assume that 25 % of wagons could be operated exclusively on the routes not depicted as "quieter". This leads to the need of 386,000 silent wagons, of which 128,000 additionally retrofitted (Option IVa).

We then assume that 25% of the population exposed to railway noise lives along the "silent routes".

Category of stakeholder	*Option*	*0*	I_a I_b	II_a II_b	III_a III_b	IV_a IV_b
RUs/Keepers and IMs	Benefits (M€)	0	0	0	0	0
	Costs (M€)	2,596	4,277 3,587	3,051 2,668	2,802 2,514	2,404 2,688
Citizens	Benefits (M€)	43,165	86,344 77,154	68,064 61,465	66,932 61,415	73,424 73,803
	Costs (M€)	1,583	2,599 2,192	2,031 1,692	1,865 1,626	2,264 2,018
Overall	Benefits (M€)	43,165	86,344 77,154	68,046 61,465	66,932 61,415	67,542 71,943
	Costs (M€)	4,180	6,876 5,779	5,353 4,435	4,907 4,264	5,238 4,982

The values presented above are NPV (20 years, 4 % discount rate).

Option	*0*	I_a I_b	II_a II_b	III_a III_b	IV_a IV_b
NPV (M€)	38,985	79,469 71,375	64,995 57,300	62,025 57,151	68,185 68,821
B/C ratio	10.33	12.56 13.35	12.71 13.86	13.64 14.40	14.02 14.81
B/C ratio rel.	1	1.22 1.29	1.23 1.34	1.32 1.39	1.36 1.43

All options have an **individual B/C** which is higher than 1 and a positive overall NPV (impacts for railways and society taken into account), which means that they could all be retained.

B/C ratios for single options are normalized by the B/C ratio calculated for the baseline. All options analysed so far have a **normalized B/C** that is greater than 1, meaning that **all options are better than the baseline**.

For further details, please refer to Annex as follows:

Railway undertakings and wagon keepers to retrofit and operate retrofitted fleet (costs) - See **Table 8: Cost of retrofitting, M€/year**

Railway undertakings, wagon keepers and infrastructure managers to operate dual fleet (costs) - See **Table 10: Administrative and logistics costs, M€/year**

	EU citizens exposed to railway noise to benefit from its reduction (benefits) - See **Table 14: Net benefit from reduced noise, M€/year** EU citizens to bear the cost of modal shift (from rail to road due to increased transport costs in rail) (costs) (only noise and climate change effects) - See **Table 12: Costs of externalities from modal shift for different options** and **Table 13: Cost of rail transport externalities due to increased traffic, M€/year** **Caveats/ Uncertainties / Risks related to the calculation model** Forecasting the development in rail freight transport and wagon fleet needs is a challenging tasks. Similarly, the pace of replacement of older "noisy" wagons is difficult to predict. They both affects considerably the CBA outcomes. Given limited practical evidence with the lifetime operating costs of wagons equipped with "silent" brake blocks, the assumed LCC may evolve substantially in the future impacting the overall results of the B/C analysis undertaken. While the costs of retrofitting are the main driver of costs in the CBA, they lead to comparable costs of externalities due to modal shift. This is estimated with the use of the cross price elasticity estimate for the shift of transport from rail to road. A single commonly accepted value for this estimate however do not exist and it is a subject to continuing discussion by transport experts. The method for monetizing costs of environmental noise from rail used in this IA is the most common approach used in health risk assessments because the methodology has been established and accepted in comparative risk analysis of WHO's EBD projects. It provides standardized estimates of the health risk due to noise that may be understood by workers in the field. However, this method requires detailed data on noise exposure, the outcome and the exposure–response relationship. Such data are not always easy to obtain and often have significant limitations. For example, the exposure-response relationships may be based on extrapolation from a small number of studies with few subjects and perhaps even a measure of noise exposure that is not available on a population basis. This means that the estimates usually suffer from a considerable degree of uncertainty. This uncertainty is very difficult to quantify, although it is sometimes possible to provide low and high limits using sensitivity analyses[13]. Introduction of quieter routes (Option IV) may lead to increased operational costs. However, these are difficult to establish. There is also no comparable operational constraint nowadays that could serve as a reference for their estimation. In order to account for uncertainty in the input values (unit costs, fleet figures, renewal rates), the sensitivity analysis is carried out with min/max range values for retrofitting costs, development in the fleet and for renewal rates.

[13] Mathers CD et al. *Global burden of disease in 2002: data sources, methods and results.* Geneva, World Health Organization, 2003 (Global Programme on Evidence for Health Policy Discussion Paper No. 54).

5. Comparison of options and preferred option

5.1. Effectiveness criterion (options' response to specific objectives)

Criteria/Option	*0*	*I*		*II*		*III*		*IV*	
Effectiveness	2.0	3.3	3.3	3.8	3.8	3.8	3.8	4.0	3.5

Under the **baseline**, there may not be sufficient motivation to remove some "noisy" wagons from wagon fleet (at least in some parts of the European Union), which would negatively impact the overall noise reduction. This is further aggravated by the fact that the relationship between the share of noisy wagons and the noise reduction is not proportionate (linear).

All regulatory **options (Option I-IV)** provide certitude and clarity to the schedule for gradual removal of "noisy" wagons, thus enabling effective fleet management and they address the problems to be solved.

5.2. Efficiency (NPV and B/C ratio) criterion

Criteria/Option	*0*	*I*		*II*		*III*		*IV*	
Efficiency	1	2.5	3.4	2.7	3.9	3.7	4.5	4.1	5.0

All regulatory options have **B/C ratio >1 and NPV >0**, thus providing a high efficiency.

Moreover **Options I-IV are all more efficient than the Baseline**.

Since the absolute B/C ratios are very similar, the options could be considered as **comparable from the efficiency point of view**.

The relative efficiency scores (in table above) show that Option III and IV are compartivelly more efficient than other Options.

5.3. Summary of the comparison

Criteria/Option	*0*	*I*		*II*		*III*		*IV*	
Effectiveness	2.0	3.3	3.3	3.8	3.8	3.8	3.8	4.0	3.5
Efficiency	1	2.5	3.4	2.7	3.9	3.7	4.5	4.1	5.0
Overall	**1.5**	**2.9**	**3.3**	**3.2**	**3.8**	**3.7**	**4.1**	**4.1**	**4.3**

Relying on the wagon fleet renewal driven purely by market forces is likely to bring very limited benefits in the years towards 2020 an even more limited beyond. This is because with the renewal rate of 2 %, the entire fleet will become silent only towards the year 2050. At the same time, the EU and national initiatives may bring an important contribution to the retrofitting of the fleet.

The choice of the year by which wagons must comply with NOI TSI requirements influences the B/C ratio as well. The options with a later application date yield higher B/C ratio as they require less wagons to be retrofitted and at the same time they gather noise reduction benefits on networks/routes where relatively more citizens are exposed to railway noise.

5.4. Preferred option(s)	This impact assessment provides evidence that all options envisaging gradual implementation (Option II-IV): - provide for effective noise reduction (effectiveness) - are largely beneficial from a combined railway-society perspective - by the order of magnitude (efficiency) - "smooth" the additional costs of the railway sector From a strict economic point of view, the margin of difference between them is not sufficient for discarding any of them. **Overall, Option III and Option IV score relatively higher than the other options.** **In case Option III is not feasible from the legal point of view (as per EC analysis), Option IV can be recommended by this Impact assessment.**
5.5. Further work required	The scope of this impact assessment is Europe-wide (NOI TSI countries). Due to specific situations in some Member States (retrofitting costs, population exposed to railway noise), the impacts of the implementation of the new regulatory requirements can be higher or lower. However, given the very high efficiency (B/C ratio) of all options, we do not expect negative outcomes of a country specific IA. Specific cases were granted to several MSs on the background of technical feasibility and economic efficiency (disproportionately high retrofitting costs). In these latter cases, country specific cost benefit analysis (CBA) may be needed to provide economic justification for specific cases. The Agency has been jointly preparing the CBA for Poland and Sweden together with the respective NSAs, as to provide evidence on the specific situations in these two countries.

6. Monitoring and evaluation

6.1. Monitoring indicators	It is recommended to set up the following monitoring indicators: › *Perceived noise at established noise measurement points (requiring to set up monitoring platform).* › *Relative share of train kms performed with trains consisting of "silent" wagons in domestic and international rail freight transport (requiring to collect data from IMs).* › *Relative share of silent wagons in the total wagon fleet (requiring to incorporate "noise" characteristics of wagons into NVR/EVR).* Ideally, all three indicators should be introduced and jointly monitored by relevant stakeholders. Good examples exists at national level demonstrating their feasibility and soundness.
6.2. Future evaluations	It can be recommended to carry out follow-up assessments to reflect real developments in the wagon fleet and their impacts. Such an assessment may be particularly useful at the time of the implementation of the new Regulation, to advice on the possible next steps. Ex post evaluation should take place five years after the introduction of the ban on "noisy" wagons to verify the validity of the input cost and benefit estimates. Further ex post evaluation may be needed five years later to confirm the previous analysis. Evaluations are also expected in the framework of the development and monitoring of the European subsidies, such as any potential future CEF calls for wagon brake blocks retrofitting.

Annex I: Data and considerations for CBA

Wagon fleet

Estimations of the current wagon fleet and of its development is based on information obtained from NSAs and other sources, such as Eurostat database. Agency's estimates cover all countries in which the NOI TSI is mandatory, i.e. EU28+CH+NO-EE-LV-LT.

For the purpose of the IA, the following totals and aggregates on wagon types have been considered:

	Wagons NOI TSI countries	Wagons in IA
Total wagons	**630,000**	**617,000**
Wagons not possible to retrofit (2)	5,000	
Maintenance&construction wag (4)	8,000	
Exempted from NOI TSI requirements	13,000	
NOI-TSI compliant New wagons	87,000	
Wagons with historic CBB (1)	4,000	91,000
Retrofitted wagons	68,000	68,000
Total NOI-TSI compliant	159,000	
Wagons costly to retrofit (3) – SS-type wagons	40,000	30,000
Wagons costly to retrofit (3) – Tyred wheel wagons	95,000	95,000
Wagons costly to retrofit (3)	125,000	125,000

(1) Wagons with historic CBBs means wagons fitted with composite brake blocks which were not approved in accordance with UIC 541-4 or ERA/TD/2013-02/INT.

(2) Wagons not possible to retrofit means Wagons for which there is no industrially available technical solution for retrofitting with LL composite brake blocks (e.g. wagons with small wheels, wagons with 1Bg or 1Bgu cast-iron brake blocks configuration)

(3) Wagons for which there is suitable technical solution for retrofitting with LL composite brake blocks but which is more complex than the 1:1 replacement of cast iron brake blocks (e.g. wagons fitted with tyred wheels, wagons that need to be equipped with wheels complying with EN 13979-1 and a kink valve, S wagons with 'SS-brake')

(4) Wagons which are used for transport of ballast and other maintenance material to and from a site of work as part of the infrastructure maintenance or wagons for purely historic or touristic use

Table 1: Assumption on the wagon fleet for NOI TSI countries

Due to the application of the NOI TSI, we assume, in cases where no detailed data are available from NSAs, that freight wagons authorized for operation in the EU since 1.1.2007 have been equipped with "silent" composite brake blocks or with disc brakes.

Wagons per MS of registration	AT	BE	BG	HR	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV
Total wagons	23345	12013	16915	2274	42199	366	20849	9942	77678	165653	3229	3755	254	25365	11888
NOI-TSI compliant New wagons	4511	2,312	568	183	7800	225	0	200	5558	25283	2,933	911	0	2783	0
Wagons with historic CBB (1)															
Retrofitted wagons	2000			200	200	0	0	0	3000	34343	0	0	100	0	0
Total NOI-TSI compliant	6511	2312	568	383	8000	225	0	200	8558	59626	2933	911	100	2783	0
Wagons not possible to retrofit (2)															
Wagons costly to retrofit (3)			12500		3927									12000	
Maintenance&construction wag (4)										1000	296				
Total Exempted wagons	0	0	12500	0	3927	0	0	0	0	1000	296	0	0	12000	0
Wagons to be retrofited (NOI TSI Rev)	16834	9701	3847	1891	30272	141	20849	9742	69120	105027	0	2844	154	10582	11888

Wagons per MS of registration	LT	LU	NL	PL	PT	RO	SK	SI	ES	SE	UK	CH	NO	NOI TSI
Total wagons	14828	3610	21226	83500	3313	29679	28661	3230	20833	11000	18246	21200	1623	629109
NOI-TSI compliant New wagons	0	1410	7500	1500	525	3614	2115	226	4278	157	2467	9168	516	86743
Wagons with historic CBB (1)				0	2598		0		567	778		100		4043
Retrofitted wagons	0	0	1500	1250		0	0	0	1936	0	13000	10068	0	67597
Total NOI-TSI compliant	0	1410	9000	2750	3123	3614	2115	226	6781	931	15467	19236	516	158279
Wagons not possible to retrofit (2)				1350			1811			1400				4561
Wagons costly to retrofit (3)				61100		22000	0			5100				116627
Maintenance&construction wag (4)					190		392					900		2778
Total Exempted wagons	0	0	0	62450	190	22000	2203	0	0	6500	0	900	0	123966
Wagons to be retrofited (NOI TSI Rev)	14828	2200	12226	18300	190	4065	24343	3004	14052	3569	2779	1064	1107	346864

Table 2: Wagon fleet of NOI TSI countries (end 2017)

(1) Wagons with historic CBBs means wagons fitted with composite brake blocks which were not approved in accordance with UIC 541-4 or ERA/TD/2013-02/INT.

(2) Wagons not possible to retrofit means Wagons for which there is no industrially available technical solution for retrofitting with LL composite brake blocks (e.g. wagons with small wheels, wagons with 1Bg or 1Bgu cast-iron brake blocks configuration)

(3) Wagons for which there is suitable technical solution for retrofitting with LL composite brake blocks but which is more complex than the 1:1 replacement of cast iron brake blocks (e.g. wagons fitted with tyred wheels, wagons that need to be equipped with wheels complying with EN 13979-1 and a kink valve, S wagons with 'SS-brake'

(4) Wagons which are used for transport of ballast and other maintenance material to and from a site of work as part of the infrastructure maintenance or wagons for purely historic or touristic use

Development in wagon fleet

Estimations of the current wagon fleet and of its development is based on information obtained from NSAs and other sources, such as Eurostat database.

Agency's estimates cover all countries in which the NOI TSI is mandatory, i.e. EU28+CH+NO-EE-LV-LT and leads to a baseline development forecast curve (baseline option) and option development forecast curve (options I-IV).

General developments in the fleet

The development in the wagon fleet size consists of:

› The development in the number of the "noisy" wagons;

  › withdrawal of noisy wagons from operation as part of operating/business optimization (overcapacity, organization, specific types not needed any more)

› The development in the number of "silent" wagons, which consists of:

  › development in the number of new wagons (taken into service after TSI requirements on wagon noise came into force) fitted with silent brakes.

  › development in the number of existing wagons (taken into service before TSI requirements on wagon noise came into force) which will be retrofitted according to the assumptions in the baseline scenario and the options

Adjustments for the fleet development forecast for baseline and options

This overall development is the result of the following underlying developments:

a) **Adjustments of the wagon fleet to the current rail freight transport volumes**
b) **Adjustments to an increase in wagon productivity**
c) **Adjustments due to expected growth in rail freight transport**
d) **Adjustments due to development in goods transported**

a) *The adjustment to the current rail freight transport volumes refers to the withdrawal of wagons put in operation in 1970-1990 when there was much higher transport demand than nowadays. Despite some adjustments were already realized, there are still too many wagons to serve demand. The remaining adjustments are expected to realize gradually over the years leading to the ban on noisy wagons.* ***We assume a reduction in total wagon fleet of 12 % by 2026 (or ban year) with no reduction afterwards.*** *This corresponds to the difference in fleet use in EU-15 countries and other countries while assuming that there is still overcapacity in EU-15 at present. (Currently, in the EU-15 countries, 11 % less wagons are needed to transport the same amount of goods as in the remaining EU Member states.)*

b) *The adjustment to an increase in wagon productivity reflects the increasing operating speed*[14]*, increasingly automatized train composition, including automatic coupling, loading and unloading of transported materials, advanced train traffic management and other factors, such as the rolling out of ERTMS that is expected to increase capacity on the rail freight network, and thereby also wagon*

[14] *(*) concerning the speed of wagons: UIP informed the Agency that currently average speed of wagons is decreasing. (100km/h instead of 120 km/h) – for 120 km/h one has to adapt the braking system with substantial installation costs.*

productivity. Continued advances in fleet management can also be expected to contribute to higher wagon productivity.

We assume a 2 % annual productivity increase of the fleet towards 2030, leading to an additional reduction in the total wagon fleet of 2 % per year. This corresponds to the annual average productivity increase over the period 2004-2013 registered in a sample of 12 EU countries (for which data are available).

Moreover, looming ban pressure should enhance the optimization in wagon fleet in the years before the ban, leading to an additional annual productivity increase of 1 %, leading to an additional reduction in the total wagon fleet of 1 % per year.

We therefore assume 3 % annual productivity increase up to ban year and 2 % annual productivity increase afterwards.

c) *The adjustment due to expected grow in rail freight traffic towards 2040. This will, everything else equal, lead to an increase in the demand for wagons. Given the past trends in total freight transport volumes, we assume a slight increase in freight tonnes kilometres of 1.2 % p.a. up to 2020 and 2.5 % p.a. onwards. This increase would lead to an increase of wagon fleet, but not at the same extent as the increase in freight traffic.* ***We therefore assume the annual increases in wagon fleet of 1 % up to 2020 and 2 % afterwards.***
(This forecasted development implies that White Paper rail transport volume targets will not be met, but they are in line with the expert opinions expressed during the mid-term review and elsewhere[15]. Also note that the development in the total freight tonne-kms was constant since 2012.)

d) *The adjustment due to the development in the nature and type of transporting goods recognizes the increased need of wagons as the goods transported by rail become lighter with relatively more finished products being transported rather than raw materials.* ***We assume a slight increase in the total wagon fleet needed of 0.25 % p.a. up to 2026 and 0.5 % p.a. onwards.*** *Here, the 0.25 % initial increase corresponds to the continuation of the trend of the ratio between the freight tonne km and freight train km since 2010.*

As per 31.12.2017, the wagon fleet for the IA countries is estimated to be 630,000 wagons. We assume that this will slightly decrease in the next ten years and almost flatten afterwards, under the baseline scenario. For all options, we assume a more important decrease in the total wagon fleet until the ban year and then a slight increase to reflect expected grown in freight transport. These reflect the overall impact of several underlying trends and forces likely to play a role for EU wagon fleet in the future (see Appendix to Annex I), notably rationalization and optimization of the fleet.

Both forecast trend lines (baseline, options) can be simplified as follows: For baseline, the total number of wagons decreases from 617,000 wagons in 2017 to 613,000 wagons in 2025. For all options with implementation date of 1.1.2025 ("options 2025"), the total number of wagons decreases from 617,000 to 515,000 by the implementation date. It then starts a slight increase trend (Figure 1).

The wagon forecast model used in the CBA however relies on a more comprehensive forecast trends, in which non-linear trends are used.

[15] McKinsey 2014: Getting freight back on track

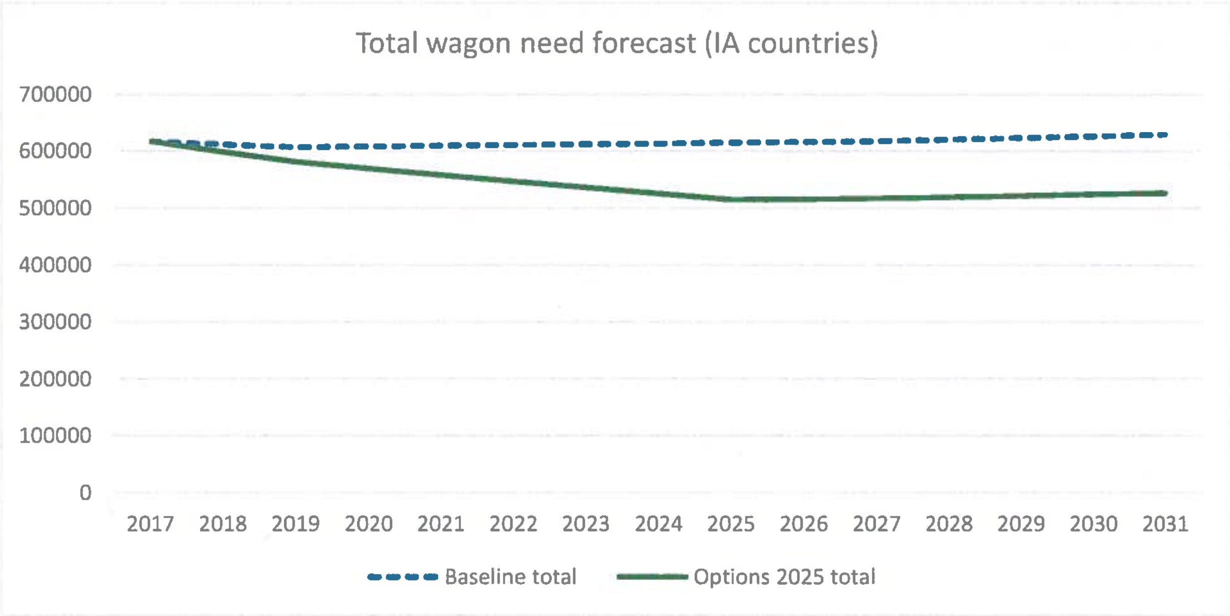


Figure 1: Total wagon fleet forecast for baseline and "Options 2025"

Fleet development for baseline

Renewal rates

We consider that only wagons with cast-iron brake blocks (CI BB) are subject to renewal, at an annual renewal rate of 2 %. (This corresponds to the renewal rate needed for wagon with an average lifecycle of 50 years.) As a consequence, once an existing wagon is retrofitted with LL BB, it is not considered to be subject to renewal within the evaluation period (ending 2037).

Retrofitting rates

Two drivers of retrofitting are considered:

The **first driver** is that keepers of wagons used in Germany and Switzerland are retrofitting their wagons fleets due to looming legal ban on noisy wagons and thanks to the availability of compensations under existing retrofitting programmes (national and European).

The **second driver** is a consequence of the first driver where railway undertakings and wagon keepers from outside Switzerland and Germany operating their wagons in Austria, Netherlands, Germany or Switzerland, will retrofit due to business opportunities. They will take advantage from the available compensation schemes for retrofitting or NDTAC bonus in Germany, Netherlands and Switzerland.

The total of 138,000 wagons should be retrofitted under the CEF I call covering the period 2014-2020, of which 17,000 wagons are assumed to be retrofitted by end 2017.

Wagons are also retrofitted under national retrofitting programmes:

As per information provided by the German Transport Ministry (BmVi), 41 companies from Germany, Belgium, France, Austria, Poland, Sweden, Spain and Switzerland have filed by the BmVi for retrofitting grants to retrofit more than 165,000 freight wagons by 2020 under the German retrofitting programme.

All Swiss-registered wagons of a little less than 9,000 wagons have been retrofitted by end 2017 under the national programme. They are not taken into account as they are not part of the 165,000 wagons envisaged to be retrofitted under the German scheme.

Retrofitting programmes were recently started in Austria, Czech Republic and France, covering several thousands of wagons in the next three years.

Since some wagons may receive both European and national subsidy, the total number of wagons to be retrofitted in years up to 2021 is not a simple sum, but an informed expert guess based on all available figures.

Based on reported data, we assume the number of retrofitted wagons to be 68,000 as of end 2017. This number should increase by 122,000 to 190,000 by end 2020, due to the drivers described above.

Above estimates lead to the fleet development for the baseline scenario shown in (Figure 2).

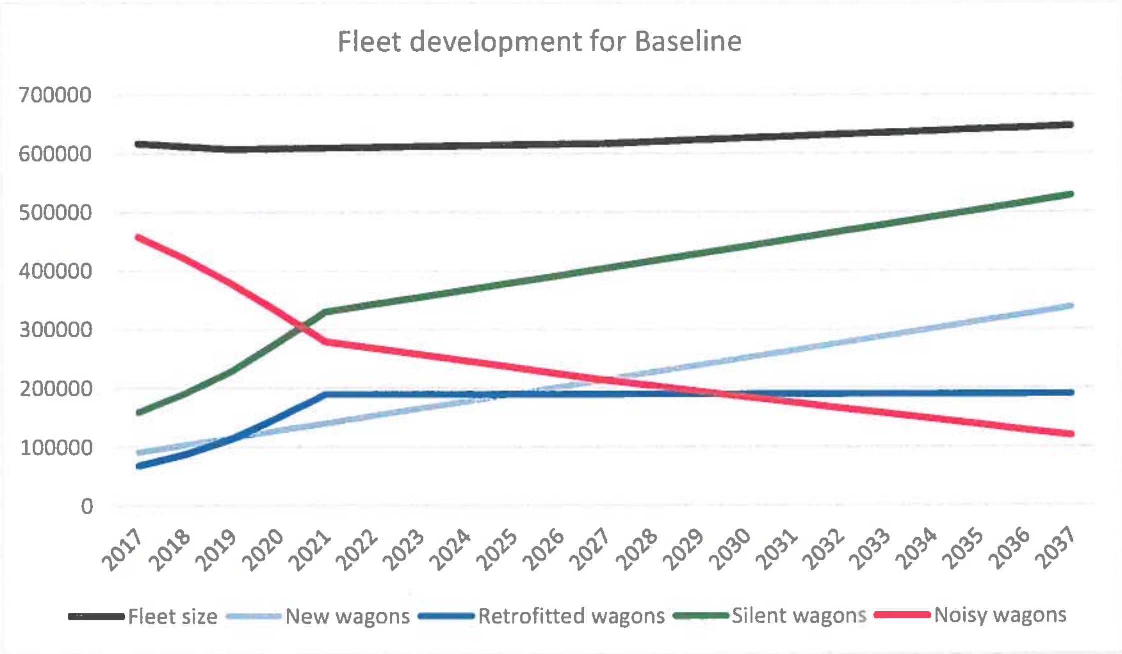


Figure 2: Wagon fleet development for the Baseline

Fleet development for options

The fleet developments in options are based on the Agency assumptions that are results of comprehensive discussions with stakeholders.

Renewal rates

The renewal rate assumed for all options is 2 %. Thus, we do not expect the regulatory measure to influence the renewal rate. The development in new wagon fleet is then identical to baseline.

Assuming the nominal rate above, the number of new wagons (replacing old wagons) is 630,000 x 0.02 each year.

Retrofitting

Retrofitting of wagons is the main driver of gradual removal of "noisy" wagons in all policy options under consideration.

The retrofitting of "noisy" wagons triggered by the revised NOI TSI requirements (ban on noisy wagons by year Y) is assumed to lead to an exponential increase in the number of "retrofitted" wagons, whereas a constant n % annual increase in the total number of retrofitted wagons throughout Europe is considered. Assuming an exponential grow is supposed to better reflect the reality whereas more retrofitting will be done in practice year by year, with the highest absolute number of retrofitted wagons in the years preceding the legal ban.

The following formulas are applied:

$N_Y = N_{Y-1} \times (1+n)$, where $n = (N_{Yb}/N_{2016})$^$(1/(Y_b - Y_{2016}))$, where

N_Y is the number of retrofitted wagons in year Y,

Y_b is the year of the implementation of the ban, and

n is annual average increase in the number of retrofitted wagons.

For example, for Option I, the number of retrofitted wagons would have to increase from 68,000 in 2017 to 267,000 in 2022. Applying the formula above: n=(267/68)^(1/(2022-2017))=0.315. So, the number of retrofitted wagons will have to increase by 32 % each year between 2017 and 2022.

Exemptions from retrofitting obligation

A small number of wagons is expected to be exempted from the NOI TSI requirements. They include:

- *Wagons not possible to retrofit: Wagons for which there is no industrially available technical solution for retrofitting with LL composite brake blocks (e.g. wagons with small wheels, wagons with 1Bg or 1Bgu cast-iron brake blocks configuration)*
- *Maintenance and construction wagons: Wagons with specific dedicated use, with a low annual mileage*

To estimate the number of exempted wagons for NOI TSI countries, extrapolation was carried out from figures available for a group of MSs, in which they represent 2.5 % (1.25 % and 1.25 % respectively). The total number of wagons assumed to be exempted from the obligation to retrofit is assumed to be 15,000.

Since the exempted wagons have very low mileage and are usually run at lower speed, their contribution to railway noise is marginal. They are therefore deduced from the total number of wagons in the model.

Wagons subject to specific case

Several Member States proposed exemptions to their fleet used on their territory on the economic or safety grounds. These are considered as noisy wagons to remain after the implementation of new NOI TSI requirements. The total number of these wagons is 125,000.

Modelled fleet development

The expected (modelled) fleet development is the results of the considerations discussed in this chapter, including various adjustments.

The expected development in the number of different types of wagons for Option Ib and Option IV is shown in Figure 3 for illustrative purposes.

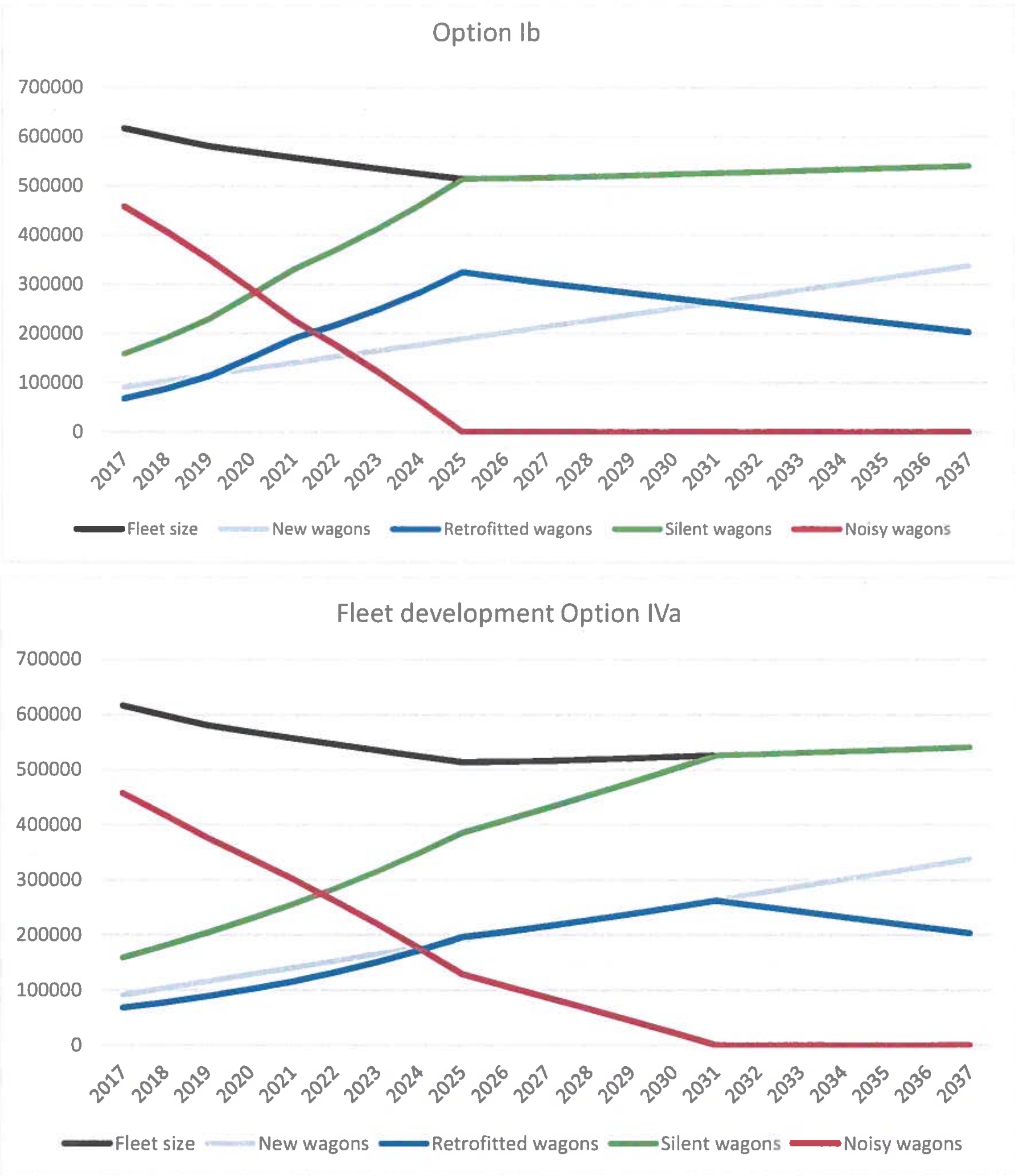


Figure 3: Total wagon fleet forecast for option IVa

Costs considerations

Four types of costs are considered in the impact assessment, as shown in Table 3.

Type of costs	Baseline	Option I	Option II	Option III	Option IV
Retrofitting (one-off and recurring)	X	X	X	X	X
Administrative and logistics (one-off and recurring)			X	X	X
Externalities due to modal shift (recurring)	X	X	X	X	X
Externalities due to increased rail traffic (recurring)					X

Table 3: Type of costs considered in the CBA

Retrofitting Costs

To calculate the costs of retrofitting, we consider the one-off installation costs, lifecycle costs on the background of an average mileage of wagons. An "average" wagon type is established as regards to the number of axles and braking blocks. However, three types of wagons are considered as regards to the installation and lifecycle costs:

S-type wagon (Bgu, s (100 km/h), not-automatic load-proportional braking system and brake linkage and slack adjuster in the middle)

SS-type wagon (Bgu, ss (120 km/h), automatic load-proportional braking system and brake linkage and slack adjuster in the middle)

Tyred-wheels wagon (Wagons on which the brake blocks cannot be retrofitted directly)

Total retrofitting costs are composed of material and labour costs incurred as one-off installation and during lifetime due to increased maintenance requirements on wheels.

The unit cost estimates below represent best to date Agency knowledge, with figures coming from the railway sector.

Average mileage of wagons

Based on several studies, we establish an average annual mileage of wagons as 45,000 km. The average number of wagons is expected to raise, it should be partly compensated by the increase in distance travelled.

Average number of axles and brake blocks per wagon

Most typical wagon axles configuration is four axles, however some wagons with other axle configurations. While their share is difficult to establish, the analysis of data records in the RSRD[2] suggests that on average, there are four axles per wagon in practice. We use this estimate in the calculation of retrofitting costs. The configuration 2xBgu is considered, meaning four brake blocks (BB) per wheel on eight wheels wagon (32 BB per wagon in total).

One-off installation/investment costs (IC) *are estimated for the above-mentioned types of wagons. They represent one-time costs expressed in costs/km. They could be translated into costs/year over remaining lifetime, assumed to be 20 years.*

Additional Life-cycle costs (LCC) *are considered to be equal for all three model types of wagons and consist notably of increased maintenance costs and increased productivity losses of wagons due to increased maintenance (expressed as opportunity costs).*

Both types of costs can be translated into uniform equivalent annual costs (EAC). However, the IC and LCC are considered separately in the cash flow of the B/C analysis.

It is assumed that 50 % of retrofitting will be done as part of the standard mandatory maintenance cycle of 6 years. Therefore, a pro-rata factor of 0.5 is applied to certain common items in table below.

One-off installation (investment) costs

Wagon/cost type	Item	Unit cost (€)	Quantity	Pro-rata factor	Total (€)
S-type wagon - additional costs	Material - brake blocks (LL)	27	4x8	1	864
	New markings on wagon	30	2	1	60
S-type wagon - replacement costs	Work - installation of brake blocks	*6.4*	*4x8*	*0.5*	*102*
	Brake test	*220*	*1*	*0.5*	*110*
	Wheels reprofiling	*160*	*4*	*0.5*	*320*
	Transport costs to workshop (one-way)	*300*	*2*	*0.5*	*300*
SS-type wagon - additional extra costs	Material - brake cylinder/ventil	675	2	1	1,350
	Work - brake cylinder/ventil	350	2	1	700
Special wagon tyred wheels - additional costs	Material – wheelset	2,600	4	1	10,400
	Work - wheelset replacement	250	4	1	1,000
S-type wagon - one-off additional costs (€)					**1,756**
SS-type wagon - ss - one-off additional costs (€)					**3,806**
Special wagon - tyred wheels - one-off additional costs (€)					**13,776**
S-type wagon - costs per km over remaining lifetime (€/km)					0,00195
SS-type wagon - ss - costs per km over remaining lifetime (€/km)					0,00422
Special wagon - tyred wheels - costs per km over remaining lifetime (€/km)					0,01486

** Costs not considered if retrofitting done as part of the main regular maintenance cycle for wheels*

Table 4: One-off installation costs of brake blocks retrofitting for different types of wagons

(1) One-off installation costs provided by stakeholders: DB: 1,688 €per 4-axle wagon. SNCF: 1,688 € per wagon and UIP: 2,219 € for s-type and 3,738 € for ss-type.
(2) Average one-off installation costs under CEF I call: 1,084 € per S-type wagon and 3,034 € per SS-type wagon (eligible costs), corresponding to 1,704 € per S-type wagon and 4,358 € per SS-type wagon

Life-cycle (maintenance) costs

Wagon/cost type	Item	Unit cost (€)		Quantity	Interval (km)		Total costs (€)		
		CI BB	LL BB		CI BB	LL BB	CI BB	LL BB	Delta
Wagon related maintenance costs	Material - brake blocks	7.00	27.00	32	75,000	100,000	134.40	388.80	254.40
	Work - replacement of BB	6.40	6.40	32	75,000	100,000	122.88	92.16	-30.72
	Disposal of organic parts	-	4.00	32	75,000	100,000	0.00	57.60	57.60
	Wheels reprofiling	160.00	160.00	4	200,000	100,000	144.00	288.00	144.00
	Wheels replacement due to wear	2 600.00	2 600.00	4	800,000	500,000	585.00	936.00	351.00
	Wheels replacement work	250.00	250.00	4	800,000	500,000	56.25	90.00	33.75
Wagon related productivity losses	Downtime costs, production loss	25.00	25.00	6	200,000	100,000	33.75	67.50	33.75
	Wagon transport to workshop	275.00	275.00	2	200,000	100,000	123.75	247.50	123.75
Additional LCC per wagon and year (€)							*1,200*	*2,168€*	**968 €**
Additional LCC per wagon per km (€)									**0.0215 €**

Table 5: Life-cycle costs of brake blocks retrofitting

	Additional LCC per wagon and year (€)	Additional LCC per wagon per km (€)
UIP	1,368	0.0304
DB (4 axle wagon)	800	0.0178
SNCF (3.4 axle wagon)	938	0.0208
CER (min)	*644*	*0.0140*
CER (avg)	1,013	0.0230
CER (max)	*2,464*	*0.0550*

Table 6: Additional life-cycle cost estimates provided by particular stakeholders

We estimate from available national data the following wagon type distribution among wagons to be retrofitted over the entire period under assessment (Table 7):

Type of wagon / TALCC	% share
S-type wagon	77 %
SS-type wagon	9 %
Tyred-wheels type wagon	14 %

Table 7: Assumed wagon type distribution in the IA countries wagon fleet

There is estimated 95,000 tyred wheels wagon in IA countries among wagons that need to be retrofitted. We assume that only 60,000 will be retrofitted. This leads to a relative share of 14 %. For 30,000 SS-type wagons, we assume that all of them will be retrofitted, leading to their relative share among wagons for retrofit of 9 %.

Table 8 shows the resulting cost of retrofitting for each option and the baseline.

Retroffiting costs	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	139	179	246	290	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184	184
Option Ia	0	168	236	333	469	661	355	344	333	322	311	302	292	283	273	264	254	245	235	226	216
Option Ib	0	139	179	246	290	284	324	371	424	303	293	283	273	264	254	244	235	225	216	206	197
Option IIa	0	128	160	201	251	314	183	217	227	238	249	392	256	247	237	227	218	208	198	189	179
Option IIb	0	100	114	130	149	169	193	220	250	227	240	254	269	284	237	227	218	208	198	189	179
Option IIIa	0	112	137	171	217	347	204	208	213	219	225	235	244	254	223	214	204	194	185	175	166
Option IIIb	0	95	108	123	141	163	189	222	261	201	207	216	225	304	223	214	204	194	185	175	166
Option IVa	0	101	115	132	150	172	196	224	255	190	190	190	190	190	190	190	190	190	190	190	190
Option IVb	0	101	115	132	150	172	196	224	255	216	223	231	240	248	257	272	235	225	216	206	197

Table 8: Cost of retrofitting, M€/year

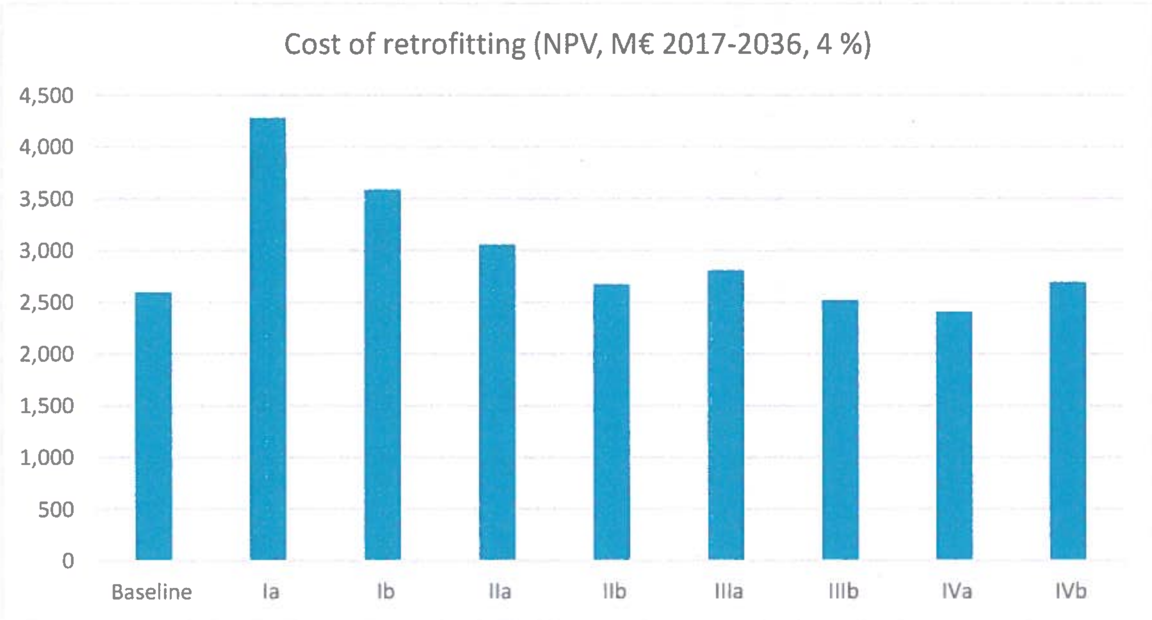


Figure 4: Net present value (NPV) of retrofitting costs for options and baseline, M€

The costs expressed as a one time net present value can be converted to a measure of uniform equivalent annual cost (EAC), using the formula below:

$$EAC_i = \frac{NPV_i}{\frac{(1+r)^t - 1}{r \cdot (1+r)^t}}$$

It should be noted that the EAC calculated with this method is an average number, and does not indicate the acutal costs that will be incurred during each year.

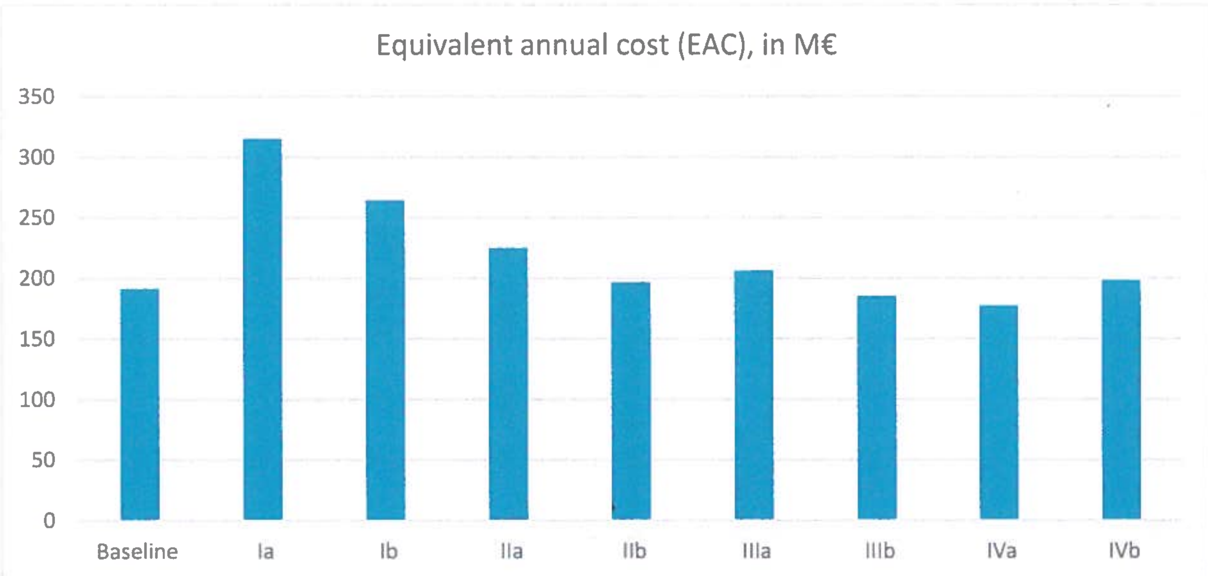


Figure 5: Equivalent annual costs (EAC), M€

Administrative and logistics costs

Different implementation scenario (Option II-IV) implies additional administrative and logistics costs, linked to the new duality of operational processes, such as:

- *Planning: embedding of duality in the IT. Taking into account duality in planning processes. Anticipation of itinerary nationally and internationally. If necessary alternative planning a fallback solution. Increased costs for IT and personnel.*
- *Delivery of silent wagons for provision of customers: No longer only from the close vicinity (homogeneous wagon fleet), but from longer distances (due to lower probability to find a suitable + silent wagon in close vicinity). Increased transport costs, increased personnel costs, lower percentage of return loads, in total an increased need of wagons due to longer circulation times, possibly lower quality of service (since no suitable wagon is available)*
- *Train formation: If necessary twice as many train formation for a destination area resulting in increased need of marshalling tracks, handling costs and lower performance (blocking of tracks until trains have been filled). Possibly lower train utilization due to higher number of trains. Possibly lower quality of service due to lower number of departures*
- *Disposition of trains in daily business/management of disturbances (e.g. construction works/ extreme weather/ temporary congestion/...). Limitation of flexibility (e.g. no noisy wagon across a silent corridor). More deviation kilometres, possibly longer journey times*

These costs were then assumed as follows:

One-off costs	**I General implementation**	**II National/ International**	**III Quieter networks**	**IV Quieter routes**
Vehicle markings for noisy wagons (RU)	0	+	+	+
Provision of wagon data into registers (RU)	0	+	+	+
Provision of route data into registers (IM)	0	0	0	++
Internal IT system updates (RU,IM)	0	+	+	+
Total (estimated)	**0**	**€ 1.5M**	**€ 1M**	**€ 3M**

Recurring costs	**I General implementation**	**II National/ International**	**III Quieter networks**	**IV Quieter routes**
Additional route compatibility check costs (RU)	0	+	+	+++
Internal IT system additional costs (RU,IM)	0	+	+	+++
Delivery of wagons (time and distance) (RU,IM)	0	++	++	+++
Train formation (time and costs)	0	++	++	+++
Total (estimated) - per wagon run	0	**€ 8**	**€ 8**	**€ 20**

Table 9: Administrative and logistics costs per wagon run, €

The unit recurring costs are applied to noisy wagons used in single wagon operational mode. It is assumed that 60 % of wagons are used in single-wagon operation mode (as compared to block train operation) and that there are 110 runs per year. This results in the annual costs summarized in Table 10.

Admin&Logistic cost	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Option Ia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Option Ib	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Option IIa	0	0	0	0	2	82	80	67	54	41	28	0	0	0	0	0	0	0	0	0	0
Option IIb	0	0	0	0	0	0	0	0	2	47	33	20	10	0	0	0	0	0	0	0	0
Option IIIa	0	0	0	0	1	72	63	55	46	38	28	19	10	0	0	0	0	0	0	0	0
Option IIIb	0	0	0	0	0	0	0	2	54	45	36	27	18	0	0	0	0	0	0	0	0
Option IVa	0	0	0	0	0	0	0	3	84	82	81	79	77	76	74	72	71	69	67	66	64
Option IVb	0	0	0	0	0	0	0	3	84	82	81	79	77	0	0	0	0	0	0	0	0

Table 10: Administrative and logistics costs, M€/year

Estimation of the impact of retrofitting on modal shift

The additional retrofitting and administrative costs (compared to the baseline scenario) born by the industry lead to an increase in the operating/production costs of rail freight transport causing a modal shift from rail to road. Since external costs of freight transport by road are higher than external costs of freight transport by rail, there are additional (external) costs associated with the retrofitting of freight wagons.

The competitiveness impact is modelled using transport cost data from the COMPETE study[16] and external costs estimates from CE Delft study[17]. Data on freight transport are taken from Eurostat.

We assume the (operating) cost of freight transport in 2016 prices to be 0.04 € per tkm for road and 0.05 € per tkm for rail. The estimate of the operating costs of rail transport represents an average for six rail freight EU operators, for which the financial indicators could be retrieved by ERA from their 2016 annual reports. Assuming no profit margin, the cost per tkm was estimated as (Turnover-EBIT)/Transport Volume. The operating cost estimate was checked against several regional studies, such as by the annual report on trans Alpine freight transport[18].

Using the 0.05 € per tkm unit operating cost for rail freight transport, the total operating costs for NOI TSI countries can be estimated as 21.15 billion €/year (423 billion tkm/year * 0.05 €/tkm).

The increase in operational costs (rail freight) can be estimated as follows for the year of the application of the new provisions when the estimated total number of wagons is 550,000. Assuming constant transport volume, the average transport volume per wagon is 770 million tkm (423 billion tkm / 550,000 wagons). The operational costs per wagon will then be 31,000 €/year. Since the average additional operating costs of retrofitted wagons is 970 €, this will mean a 3% of increase of operating costs.

In order to estimate the costs of modal shift, a cross price elasticity needs to be introduced to reflect relative shift of goods transported from rail to road. The elasticity estimates provided by literature can range from approximately 0 to 7. (Many of the values cluster around 0.5 for bulk freight or 4 for finished goods.) However, the values most commonly accepted are in the range from 0.9 to 1.6.

The percentage of ton-kilometers that switches modes in response is calculated (for each combination of origin, destination, and commodity) as:

$$\exp(\varepsilon_{r,d} \times \ln[(1+C_d)/(1+C_r)]) \approx R_c \times \varepsilon_{r,d}$$

where R_c is the relative change in total shipping costs for one mode versus the other, and $\varepsilon_{r,d}$ is the cross price elasticity of the "receiving" mode (here trucks) with respect to the "donating" mode (here trains). The expression inside ln[•] is the percentage increase in the total cost to ship (a commodity on a route) by the donating mode relative to the receiving mode, based on their respective absolute percentage increases C_d and C_r.

[16] COMPETE final report, Analysis of the contribution of transport policies to the competitiveness of the EU economy and comparison with the United States

[17] Update of the Handbook on External Costs of Transport (2014), Final report

[18] Observation et analyse des flux de transports de marchandises transalpins, Rapport annuel 2014

So, if train shipping costs increased by 10 percent relative to road for a particular commodity on a particular route, and if the cross-price elasticity was 1.2, road ton-miles for that commodity on that route would increase by exp(1.2 × ln[1.1]) = 1.12, or 12 percent.

Assuming average cross mode price elasticity of 1.25 (middle value of suggested low and high elasticity estimate)[15], the effect on road transport and rail transport volume is established. The effect on rail transport volume is a decrease in freight tkm by rail of less than 1 % (and consequently the same increase in road freight transport). This corresponds to the shift of 1-4 million tkm per year from rail to road.

Average external costs of transport by mode expressed in EUR per tkm (taken from the CE Delft study) are multiplied by the transport amount of shifted tkm between the two modes. Since the unit values were available for 2008 only, we estimated the 2017 values by adjusting for GDP (here, by multiplying with a factor of 1.14).

The external costs of congestions were only available per vehicle kilometre. The unit values per tkm were derived by assuming average HDV load of 14 tonnes and 80 % average load factor.

External costs of transport (€/1,000 tkm)	**2008**		**2017**	
	Road	Rail	Road	Rail
LOW scenario				
All externalities except congestions	24.6	5.3	28.04	6.04
Congestion	1.5	0	1.71	0
Total			**29.75**	**6.04**
HIGH scenario				
All externalities except congestions	34	7.9	38.76	9.01
Congestion	2.5	0	2.85	0
Total			**41.61**	**9.01**

Table 11: Unit costs of transport externalities (CE Delft 2014)

Among all externalities, all main externalities (climate change, nature and landscape, biodiversity, soil and water pollution, urban effects) are included.

The impact of the cost of modal shift due to retrofitting costs is illustrated below, reflecting a situation where the retrofitting costs lead to an increase in operating costs of rail freight transport of 0.4 %.

Percent increase in rail freight price	*0.40 %*
Cross price elasticity	*-1.25*
Shift of transport volume (million tkm)	*2,378*
Relative shift in %	*-0.504 %*
Cost of change in road transport externalities (€)	*70,740,403*
Cost of change in rail transport externalities (€)	*-14,364,909*
Cost of modal shift for all externalities (€)	***56,375,494***

These extra external costs caused by modal shift have to be however put into perspective with the modal shift external costs caused by inaction (baseline scenario). This is assured through comparing the B/C ratios of options with the B/C ration of the baseline.

The costs of modal shift for different options are shown in Table 12.

Externalities costs	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	78	102	141	168	108	109	110	111	112	113	114	115	116	118	119	120	121	122	124	125
Option Ia	0	78	102	141	168	166	192	222	256	185	180	176	171	167	163	158	153	148	144	139	134
Option Ib	0	78	102	141	168	166	192	222	256	185	180	176	171	167	163	158	153	148	144	139	134
Option IIa	0	72	91	115	146	232	156	170	170	170	170	244	161	156	152	147	142	137	132	127	122
Option IIb	0	56	65	75	86	99	114	131	152	167	168	170	175	180	152	147	142	137	132	127	122
Option IIIa	0	63	78	98	126	245	158	157	156	156	156	158	159	161	143	138	133	128	123	118	112
Option IIIb	0	53	61	70	82	95	112	133	190	149	149	151	152	193	143	138	133	128	123	118	112
Option IVa	0	57	65	75	87	100	116	135	205	166	166	167	168	168	169	169	170	171	171	172	172
Option IVb	0	57	65	75	87	100	116	135	205	182	187	193	199	157	165	176	153	148	144	139	134

Table 12: Costs of externalities from modal shift for different options, M€/year

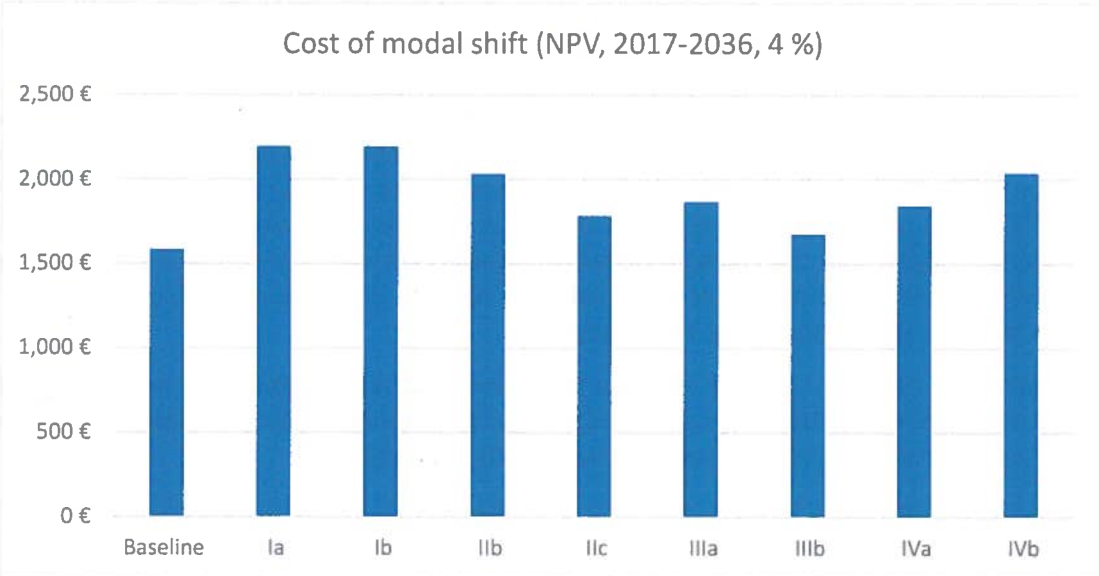


Figure 6: Net present value (NPV) of the cost of modal shift in M€

Externalities due to increased rail traffic

In particular case of Option IV (quieter routes), some trains may be operated in such a way that they avoid quieter routes. This would lead to increased traffic volume and thus additional externalities from rail transport. We estimate the rail traffic (in tonne-km) to increase by 0.3 %. Assuming the unit costs per single externalities defined in the previous chapter, the additional rail externalities cost are summarized in Table 13.

Rail externalities co	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Option IVa	0	29	29	29	29	30	30	30	31	31	31	32	32	32	33	33	33	34	34	34	35
Option IVb	0	19	19	19	20	20	20	20	20	21	21	21	21	0	0	0	0	0	0	0	0

Table 13: Cost of rail transport externalities due to increased traffic, M€/year

Valuation of noise impacts

Noise pollution can be defined as the 'unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity' (see Directive 2002/49/EC).

The economic cost of noise is given by:

- the annoyance that results in any restrictions on enjoyment of desired activities[19];

[19] European Commission (2003): *Valuation of noise*

• negative effects on human health, e.g. risk of cardiovascular diseases (heart and blood circulation[20];

• property value lose

The recommended method for monetization is stated preferences for a direct measurement of Willingness to Accept (WTA) compensation or Willingness to Pay (WTP) for noise reductions. A hedonic price method, which measures the economic cost of additional noise exposure with the (lower) market value of real estate could be used, where for the amount of houses affected by noise and the average house price a total cost can be calculated[21].

We apply the stated preference methodology (i.e. WTP for reducing annoyance and health damages) as proposed by the WHO[22] (economic burden of disease method). The latest available evidence under WHO is used[23].

After reviewing the available scientific evidence supporting causal association, the following diseases were identified as relevant for environmental noise impact assessment: cardiovascular disease, cognitive impairment by children, sleep disturbance, tinnitus and annoyance. Among them, the scientific evidence remains insufficient to reliable determine health impacts for cognitive impairment and tinnitus, while the available evidence suggest that the costs of those two diseases are marginal compared to the three other diseases. Therefore, the monetization of the burden of disease (EBD) from the rail noise is limited to cardiovascular disease, sleep disturbance and annoyance.

The EBD is expressed as the number of deaths and the metric disability-adjusted life year (DALY), which combines the concepts of (a) potential years of life lost due to premature death and (b) equivalent years of "healthy" life lost by virtue of being in a state of poor health or disability.

The DALY is calculated as the sum of the time lived with disability (YLD) and the time lost due to premature mortality (YLL) in the general population:

$DALY = YLD + YLL$

The YLD is the number of incident cases (I) multiplied by a disability weight (DW) and an average duration of disability in years (L):

$YLD = I \cdot DW \cdot L$

The YLL essentially corresponds to the number of deaths (N) multiplied by the standard life expectancy at the age at which death occurs (L):

$YLL = N \cdot L$

The approach to estimating total disease burden can be summarized in the following steps:

i. Estimating the exposure distribution in a population, here taken from END measurements;
ii. Selecting one or more appropriate relative risk estimates from the literature, generally from a recent meta-analysis (here using WHO recommended values)
iii. Estimating the population-attributable fraction with the formula for population-attributable fraction, in order to quantify the contribution of the risk factor to a disease or death. This is referred to as the exposure-based approach.

[20] Babisch (2013): *Health effects of traffic noise*

[21] Guide to cost-benefit analysis of investment projects, EC DG Regio, 2014

[22] Prüss-Üstün A et al. Introduction and methods: assessing the environmental burden of disease at national and local levels. Geneva, WHO, 2003

[23] Special Issue "WHO Noise and Health Evidence Reviews", International Journal of Environmental Research and Public Health (ISSN 1660-4601), 2018

In the exposure-based approach, the distribution of noise exposure within the study population to estimate the fraction of disease in the population that is attributable to noise is determined. This is then applied to the disease estimates. This approach requires the measurement or calculation of:

a. *the distribution of the exposure to environmental noise within the population (prevalence of noise exposure);*
b. *the exposure–response relationship for the particular outcome;*
c. *a population-based estimate of the incidence or prevalence of the outcome from surveys or routinely reported statistics; and*
d. *a value of disability weight (DW) for each health outcome.*

Ad a) The population exposed to rail noise L_{DEN}>55 db per defined noise bands is taken form the latest END measurement data available on EEA website[24]. (Data submitted by EEA member countries until 15 April 2016.)

The exposed population, i.e. number of people living in each of the affected areas identified in the noise maps is taken from EEA and represents the number of people exposed (reported) to railway noise of > 55 dB Lden, inside and outside urban areas[25]. The data correspond to data reported on strategy noise mapping due by December 2012. In practice, the results includes the most recent updates/late deliveries - up to 30th of June 2015.

Ad b) The odd ratios (incidence) for particular outcome are estimated using the formula recommended by WHO in its 2011 report Burden of disease from environmental noise (WHO BOD)[26].

For cardiovascular disease:

$$OR = 1.63 - 6.13 \cdot 10^{-4} \cdot L^2_{day,16h} + 7.36 \cdot 10^{-6} \cdot L^3_{day,16h}$$

The OR are then calculated for mid-points of noise bands under consideration:

L_{DEN} in dB	55-59	60-64	65-69	70-74	75+
OR	1.0	1.015	1.067	1.161	1.302

Note: The OR for myocardial infarction was taken for all other ischaemic heart diseases, because it can be assumed that railway traffic noise has the similar impact on all ischaemic heart disease as on myocardial infarction, as there is no exclusive causal mechanism postulated specifically for myocardial infarction.

For sleep disturbance, the proportion of highly disturbed people:

$$\% HSD = 11.3 - 0.55 (L_{night}) + 0.00759 (L_{night})^2$$

L_{NIGHT} in dB	50-54	55-59	60-64	65-69	70+
RR	1.0334	1.0447	1.0657	1.0876	1.1132

For noise annoyance, percentage of "highly annoyed" persons (HA):

$$\%HA = 7.158 \cdot 10^{-4} (L_{dn} - 42)^3 - 7.774 \cdot 10^{-3} (L_{dn} - 42)^2 + 0.163 (L_{dn} - 42)$$

L_{DEN} in dB	55-59	60-64	65-69	70-74	75+
RR	1.0344	1.0641	1.1122	1.1841	1.2851

[24] Reported data on noise exposure covered by Directive 2002/49/EC, available on EEA website
[25] European Environmental Agency (2014): Noise in Europe 2014
[26] Burden of disease from environmental noise, Quantification of healthy life years lost in Europe, WHO and JRC, 2011

Ad c) Population-based estimate of the incidence or prevalence is derived by firstly establishing the risk attributable population by multiplying the aattributable fraction, being the portion of the incidence rate of a given outcome in a given population that is identified as due to a given exposure, with the relative risk. The incident rates are then taken from Eurostat/WHO reports.

The relative risk is ratios for each noise band is taken from the WHO EBD study, whereas it is assumed that the values established for road noise can be used for rail noise.

Ad d) The value of DW for each disease is taken from WHO EBD study.

Disability weights allow non-fatal health states and deaths to be measured under a common unit[27]. DWs quantify time lived in various health states to be valued and quantified on a scale that takes account of societal preferences. DWs that are commonly used for calculating DALYs are measured on a scale of 0-1, where 1 represents death and 0 represents ideal health.

The values of DWs for various disease states have been the subject of considerable discussion and work. They are generally derived from expert panels. This work has been documented extensively[28] and will not be summarized further here. WHO has a reasonably comprehensive list of DWs and these are recommended for use. If there is no appropriate DW, then an expert committee may be asked to find an appropriate DW by analogy with other known DWs.

Disease	Disability weight (DW)
Ischemic heart disease and stroke	0.02
Annoyance	0.03
Sleep disturbance	0.07

Value of railway noise impact

Applying the methodology outlined above, the impacts of railway noise can be monetized using the DALY approach.

In case of cardio-vascular diseases, where DALY=YLL+YLD, the YLL and YLD were calculated using the generalized YLL and YLD estimates provided by WHO[29] (expressed in relative terms), which were then multiplied by the total population and by the attributable population fraction.

In case of annoyance and sleep disturbance, the DALY were calculated directly by multiplying the attributable population fraction with the number of persons exposed to $L_{den}(L_{night})$ above 55(50) dB respectively and with the disability weight.

Economic cost calculation using values of life-years (VOLYs)

We make use of units of VOLY (sometimes called the value of a statistical life-year (VSLY)) to derive the economic costs of railway noise. We use medium and mean values of 57,700 and 133,000 € respectively to

[27] Description and measurement of environmental noise. Part 2. Guide to the acquisition of data pertinent to land use. Geneva, International Organization for Standardization, 1991 (ISO1996-2:1987)

[28] Mathers CD et al. Global burden of disease in 2002: data sources, methods and results. Geneva, World Health Organization, 2003 (Global Programme on Evidence for Health Policy Discussion Paper No. 54

[29] Global Health Estimates 2015: Disease burden by Cause, Age, Sex, by Country and by Region, 2000-2015. Geneva, World Health Organization; 2016

calculate the economic cost of railway noise. These values were used in the latest EC assessment of air pollution costs in Europe[30].

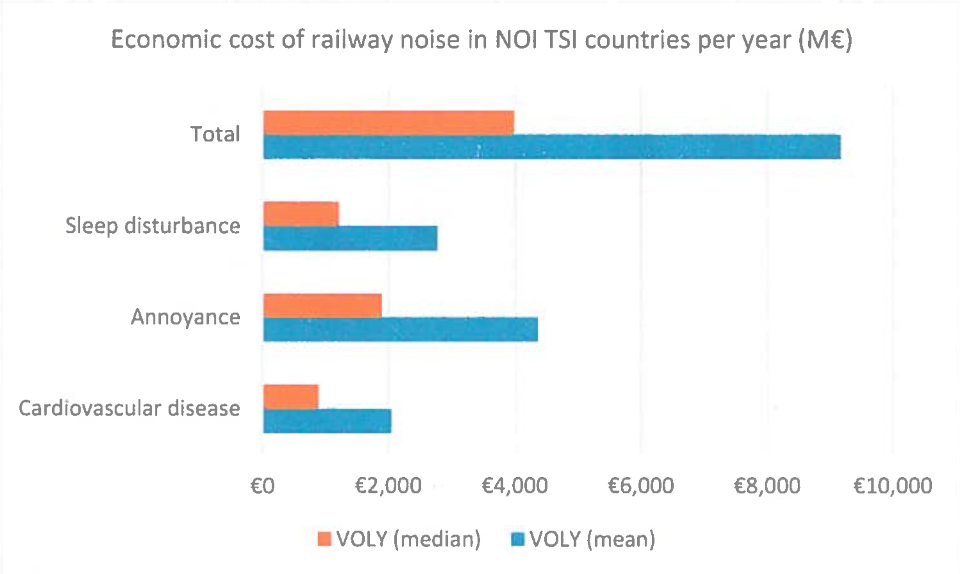


Figure 7: Value of railway noise in NOI TSI countries, M€/year

The resulting economic cost of railway noise in NOI TSI countries can be then estimated as EUR 9.1 billion per year (4 billion with conservative VOLY) (Figure 7).

Estimation of benefits from noise reduction

The volume of noise (dB(A)) avoided thanks to the reduced noise generated by rail freight wagons is estimated from the share of "noisy wagons" in the fleet. We assume that the fully silent wagon fleet would correspond to the 8 dB noise reduction. We assume the relationship between the share of silent wagons and the emitted noise to be non-linear (convexity), where higher share of silent wagons brings proportionally more noise reduction. We applied the log function developed by COWI to estimate the corresponding emitted noise.

Once the dB noise reduction has been estimated, the population exposed to noise as per different noise bands, has to be estimated. For simplicity reasons, this is done by assuming proportionate reduction in population in single dB noise bands. Here we rely on the statistics of people exposed to railway noise available in the END measurement that shows the number of people exposed to different noise bands (L_{den}):, 55-59, 60-64, 65-69, 70-74, 75+. For a given noise reduction, there is a proportionate shift of population from higher noise bands to lower ones. E.g. Each 1 dB reduction results in a 20 % shift of people from a higher noise band to the next lower noise band.

[30] Cost-benefit Analysis of Final Policy Scenarios for the EU Clean Air Package, V.2, Mike Holland, EMRC, 2014

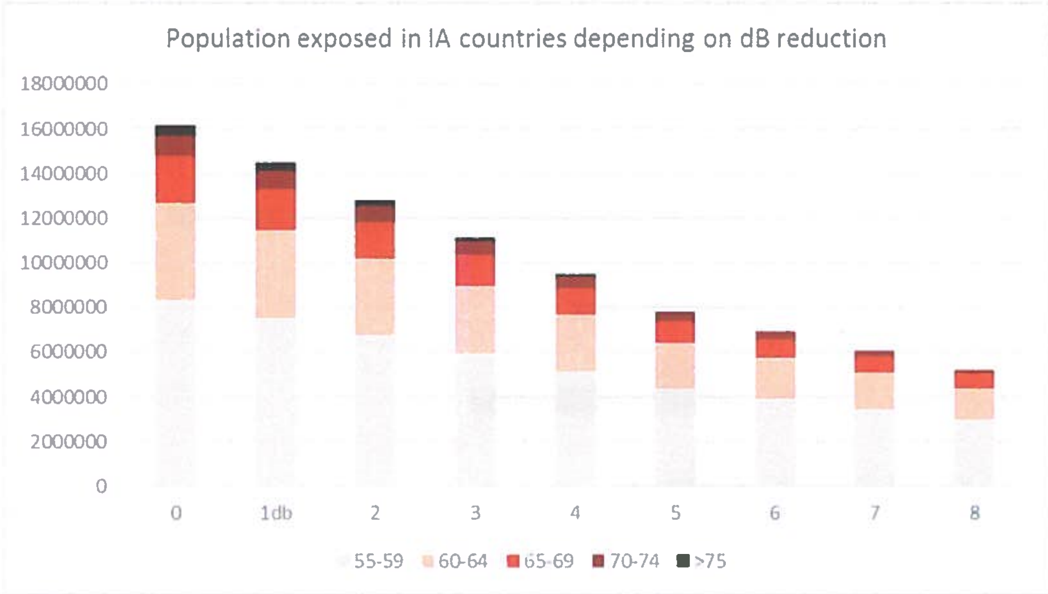


Figure 8: Population exposed to railway noise above 55dB in NOI IA countries resulting from different noise reductions

The resulting value of noise reduction per year for options and for the baselines are shown below

Benefits	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	296	887	1478	2218	2513	2661	2809	3105	3252	3548	3696	3992	4140	4435	4583	4879	5027	5322	5618	5766
Option Ia	0	444	1331	2513	4731	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872
Option Ib	0	444	1035	1774	2809	3844	5174	6327	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872
Option IIa	0	296	887	1478	2365	3400	3400	4140	4879	5766	6257	7872	7872	7872	7872	7872	7872	7872	7872	7872	7872
Option IIb	0	296	591	1035	1478	1922	2661	3400	3400	5322	6047	6608	7170	7872	7872	7872	7872	7872	7872	7872	7872
Option IIIa	0	480	1022	1711	2610	3982	4241	4586	4932	5450	5968	6446	6884	7541	7541	7541	7541	7541	7541	7541	7541
Option IIIb	0	246	554	861	1230	1723	1934	2171	2515	2515	2515	2515	2515	2515	2515	2515	2515	2515	2515	2515	2515
Option IVa	0	444	998	1589	2218	3142	4029	5081	6255	6716	7101	7382	7645	7908	8137	8347	8558	8681	8681	8681	8698
Option IVb	0	444	998	1589	2218	3142	4029	5081	6483	6897	7329	7715	8137	8628	8242	8242	8242	8242	8242	8242	8242

Table 14: Net benefit from reduced noise, M€/year

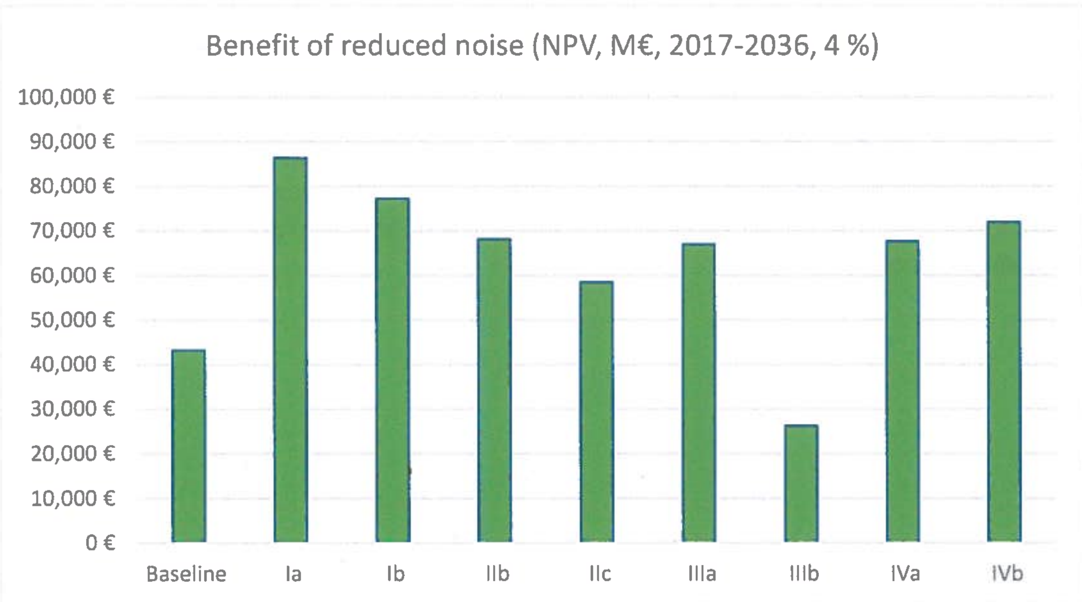


Figure 9: Value of reduced railway noise NPV, M€

Cost benefit analysis (CBA)

The estimation of B-C ratios in the CBA is carried using Net Present Value (NPV) estimations for the period of 20 years and the discount rate of 4 %. Costs of externalities due to modal shift and due to additional traffic are presented together in Table 15.

NPV (4 %, 20 years)	Retrofitting costs	Admin&Logist. costs	Cost of externalities	Total costs	Total benefits	B/C	B/C rel
Baseline	2,596	0	1,583	4,180	43,165	10.33	1.00
Ia	4,277	0	2,599	6,876	86,344	12.56	1.22
Ib	3,587	0	2,192	5,779	77,154	13.35	1.29
IIa	3,051	271	2,031	5,353	68,046	12.71	1.23
IIb	2,668	76	1,692	4,435	61,465	13.86	1.34
IIIa	2,802	240	1,865	4,907	66,932	13.64	1.32
IIIb	2,514	125	1,626	4,264	61,415	14.40	1.39
IVa	2,404	571	2,264	5,238	73,424	14.02	1.36
IVb	2,688	276	2,018	4,982	73,803	14.81	1.43

Table 15: Net present value (NPV) in CBA for all options, M€

NPVs for single cost types are summarized in Figure 10.

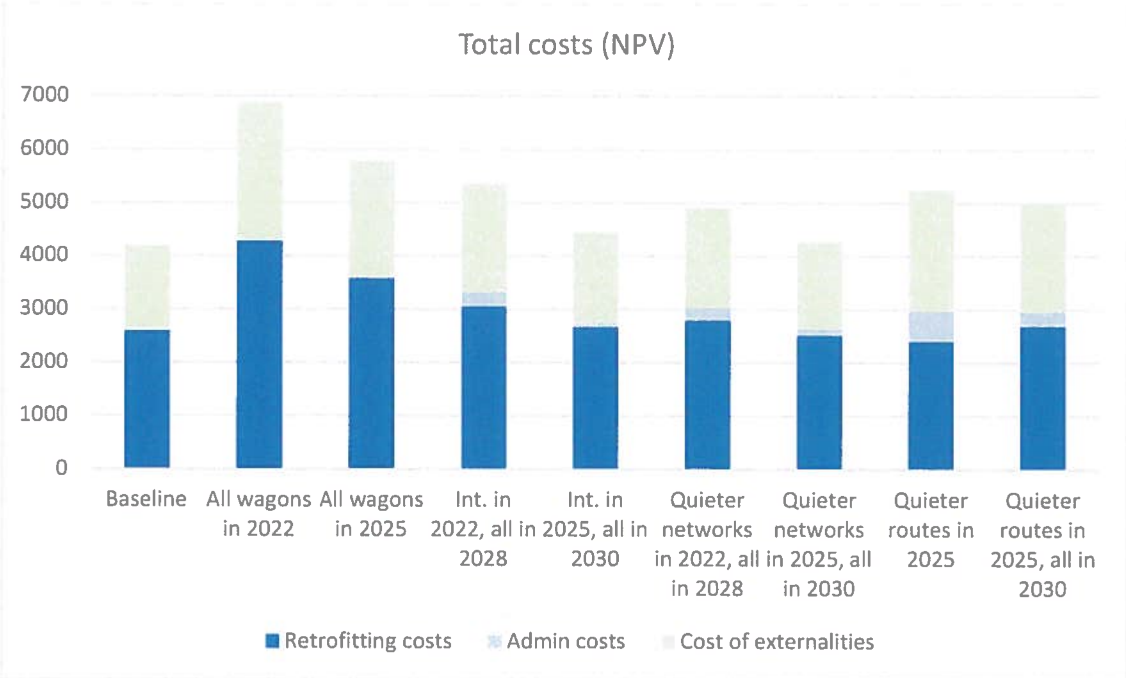


Figure 10: Costs net present value (NPV) in CBA for all options, M€

Relative comparison of the efficiency of options should be made with the use of relative B-C ratios (B-C ratio of options normalized by B-C ratio of the baseline) in Figure 11.

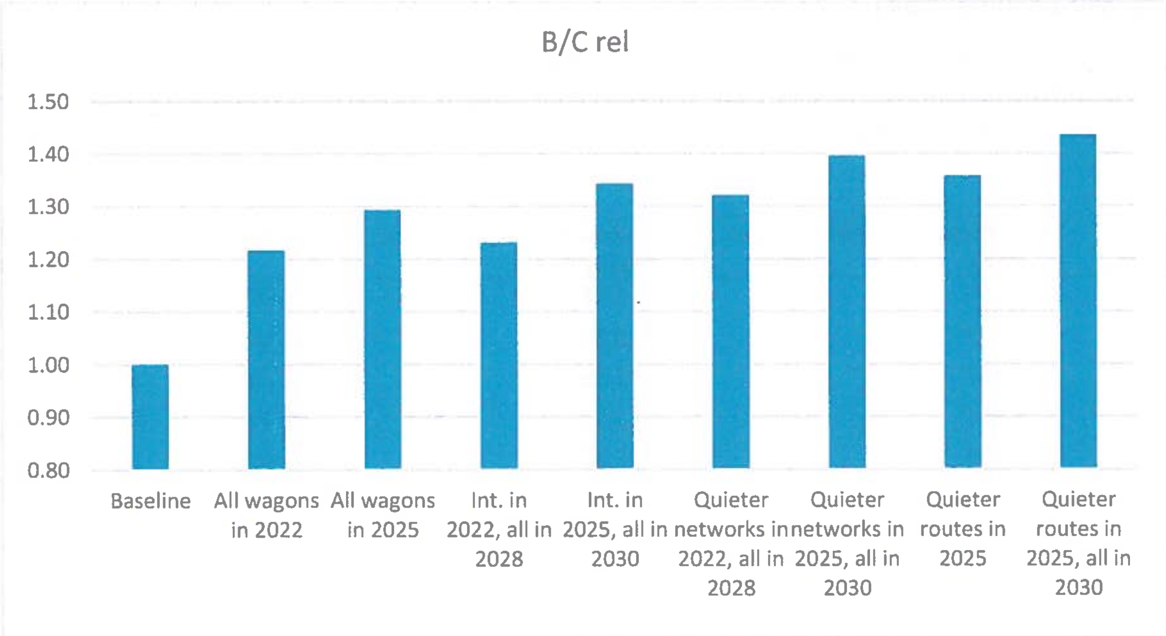


Figure 11: Relative B/C ratios for all options

Risk assessment

Sensitivity analysis

Sensitivity analysis enables the identification of the critical variables that have the largest impact on the economic performance. It is carried out by varying one variable at a time and determining the effect on that change on the NPV.

The min/max values provided for the input variables will be further tested to determine B/C ratio after adjustments for min/max values. Min value is defined as the 1.25 multiplier of the original value, while max value is defined as 0.75 multiplier of the original value. The relative effect on the B/C ratio is then summarized in Table 16.

Variable	MIN (Avg +25 %)	MAX (Avg -25 %)
One-off retrofitting	-2 %	+2 %
Life-cycle retrofitting	-4 %	+4 %
Admin&logistics costs	-1 %	+1 %
Externalities costs	-1 %	+1 %

Table 16: Impact of variable change on resulting B-C ratio -sensitivity analysis

The impact of cost variable change on B-C ratio is relatively small. This is mostly due to high benefits from reduced noise. It can be concluded that even significant changes in cost input variables do not result in B-C ratio lower than one.

Annex II: Proposed monitoring indicators

The core indicators of progress towards meeting the policy objectives are presented in the table below.

Objective	Indicators	Type	Potential Source	Reporting requirement
General objective				
Increase quality of life and wellbeing of citizens living close to railway lines	Total noise reduction on affected population	Quantitative	Commission – EEA/Member States	Per END reporting
	Noise reduction at particular hot spots	Quantitative	MS	Periodic
Support the development of rail transport and functioning of the single European rail area.	Modal share of rail transport	Quantitative	Eurostat	Yearly
Operating objectives				
OO1:Reduce the level of rolling noise emitting from freight wagons	Number of people exposed to railway noise above L_{DEN}=70dB	Quantitative	Commission – EEA/Member States	END reporting, available in 2022[31]
	Number of people in Europe exposed to railway noise above L_{night} = 60dB	Quantitative	Commission – EEA/Member States	END reporting, available in 2022
	Number and age of "noisy wagons" in operation	Quantitative	ERA/ Virtual Wagon Register	Yearly or periodical
	Number of retrofitted wagons	Quantitative		
OO2: Avoid noise triggered obstacles to the growth of rail transport	Number and content of complaints from citizens	Qualitative	Member States, Commission, representative organisations	Continuous
OO3: Avoid noise triggered obstacles to interoperability and internal market;	Development of unilateral national measures related to rolling noise and causing technological barriers for cross border operations	Qualitative	Member States/ Commission	Continuous
OO4: Maintain competitiveness of rail freight vis-à-vis road freight.	Cost per tkm, rail and road	Quantitative	Eurostat	Yearly
	National subsidies - €, number of wagons CEF grants - €, number of wagons NDTAC bonuses - €, number of km	Quantitative	Member States/ IMs/ the Innovation and Networks Executive Agency	Every 2 years

31 The END requires the Member States to no later than 30 June 2022 update the noise maps for all major roads, railways, airports and agglomeration (Art. 7). Such noise maps are prepared for the previous calendar year. I.e. the strategic roadmaps scheduled for delivery in 2022 will provide data for 2021.

Most of the data listed above is already available or can be acquired on an ad hoc basis. New reporting requirements will be linked to subsidies and NDTAC bonus payments, however authorities would need to keep track of these figures at any case. Additional burden is arising solely from forwarding this information to the Commission, and would be minimal. In addition, so far only two Member States (NL and DE) and CH apply subsidies and/or NDTAC schemes.

There is however one domain where there is clear issue with availability and quality of data – statistics on the size and composition of freight wagon fleet. This information is not only necessary for monitoring the effects of rail noise policies, but also for other aspects of rail policy. The remedy should be provided by the EU Virtual Vehicle Register, as it gets step-by-step filled up.

Annex III: Glossary of terms

NOISE

dB scale	A logarithmic scale to measure sound pressure level. A two-fold increase in sound energy (e.g., two identical jackhammers instead of one) will cause the sound pressure level to increase by 3 dB. A ten-fold increase in sound energy (10 jackhammers) will cause the sound pressure level to increase by 10 dB, which is perceived as about twice as loud.
Exposure level	Yearly average value of L_{DEN}, measured or addressed outside in front of the façade, at a height of 4 m above ground. As the exposure relates to the incident sound only, 3 dB has to be subtracted from the measured level as this is supposed to be representative for the sound reflected back from the façade.
L_{max}	The highest sound pressure level in a given time period.
L_{DEN}	L_{DEN} (Day-Evening-Night-Level), also referred to as DENL, is the A-filtered average sound pressure level, measured over a 24 h period, with a 10 dB penalty added to the night (23:00–07:00 h or 22:00–06:00 h, respectively), and a 5 dB penalty added to the evening period (19:00–23:00 h or 18:00–22:00 h, respectively), and no penalty added to the average level in the daytime (07:00–19:00 h or 06:00–18:00 h, respectively). The LDN measure is similar to the L_{DEN}, but omits the 5 dB penalty during the evening period. The penalties are introduced to indicate people's extra sensitivity to noise during the night and evening. Both L_{DEN} and LDN are based on A-weighted sound pressure levels, although this factor is not usually indicated in subscript.
Noise	Noise is general expression for unwanted sound.
Noise level	An indicator of either energy emitted by a specific sound source (production) or for the incident intensity at a specific spot (reception). Expressed in decibels.
Pass-by noise level	The equivalent level of an entire pass by event.
Sound	Vibration of particles in air, audible to a healthy human being.
Sound pressure level	Sound pressure level is a logarithmic measure of the effective pressure of a sound relative to a reference value. It is measured in decibels (dB, see below) higher than a reference level. The reference sound pressure in air is 20 µPa (2×10−5 Pa), which is thought to be the human hearing threshold at a sound frequency of 1000 Hz.

COST BENEFIT ANALYSIS

Disability-Adjusted Life Year (DALY)	Measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.
Net Present Value (NPV)	Difference between the present value of cash inflows and the present value of cash outflows.

Internal rate of return (IRR)	Interest rate at which the net present value of all the cash flows (both positive and negative) from a project or investment equal zero.
Discounting	Procedure used to compare costs and benefits that occur in different points of time on a common basis, normally the present time.
TALCC	Total additional life cycle cost
VOLY	Value of life year
VSL	Value of statistical life
WTP	Willingness to pay