EUROPEAN
UNION
AGENCY
FOR RAILWAYS

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work better for society.

Full Impact Assessment

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

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Document History

Version	*Date*	*Comments*
Draft 1.0	15. September 2016	First draft for comments from TF members
Draft 2.0	22. December 2016	Intermediate second draft for information
Draft 3.0	12. May 2017	Intermediate draft following the closure of the TF
Draft 4.0	15. November 2017	Draft following the 2. meeting of the WP
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Contents

This report (V.4) summarizes the intermediate results of the impact assessment (IA) performed by the Agency with the support of the Working Party on the Revision of the Noise TSI (Application of NOI TSI requirements to existing freight wagons).

Note that some costs impacts related to Option IV could not yet be quantified. This will lead to adjustments in the efficiency assessement (B/C ratio) and may thus influence the overall assessment.

Similarly, the wagon input data (wagons per type, wagons excluded from the application, …) are under revision, notably awaiting inputs from NSAs (NSA questionnaire).

This document is meant for information to the members of the WP, who are invited to submit any substantial comments and inputs.

1. Context and problem definition

1.1. Problem and problem drivers

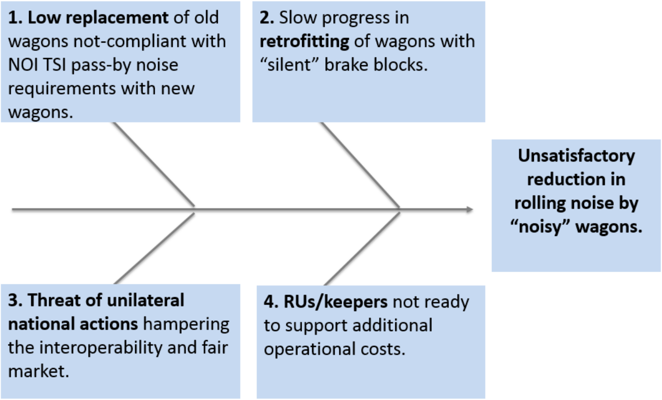
According to a recent Eurobarometer survey, 29 % of EU-28 citizens are often or very often disturbed by traffic noise; **of these, 13 %** are affected by rail noise[1]. The European Environment Agency (EEA) estimated in 2017 that railways are the second most dominant source of environmental noise in Europe, with nearly 20 million people affected[2].

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 than the function of the density of population in the vicinity of the railway lines, and to a lesser degree, of the frequency of trains.

Passenger rolling stock including high speed trains, are in many cases equipped with relatively silent disc brakes and, unlike the freight wagons, they rarely operate during night time. Consequently they are considered less of an issue.

Due to existing and growing public concern about railway noise, two countries in Europe, 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), 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.



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[1] 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)

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

1.2. Main assumptions

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. In a first step, the roughness of cast-iron braked wheels must be eliminated. Further progress can be best assured by addressing both elements in parallel. Core measures include “silent brakes” (Composite brake blocks (e.g. LL- and K-blocks), and disc-brakes) and acoustic grinding of tracks.

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 7-10 dB.

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 put into operation before that date, about 86% of the total current wagon fleet 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. Retrofitting of brake blocks, while having immediate direct effect in noise reduction, represent a financial burden to the wagon keepers and railway undertakings operating the wagons due to an increase in life-cycle operating costs (LCC).

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. They are about 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 subsistence to the industry 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 TF 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	According to Member State reports compiled by the European Environment Agency (EEA) in 2013, railway noise affects about 7 million EU inhabitants at day time, with a noise exposure above 55 dB(A). In fact, the real figures are undoubtedly higher since the EEA's European noise mapping initiative concentrates on agglomerations with over 100,000 inhabitants and on main railway lines with over 30,000 trains per year. 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). Noise is an annoying phenomenon, contaminating the environment and adversely affecting the health of people exposed to high ambient noise levels above 70 dB(A) – or even less. These 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. Railway noise is largely a problem of freight trains, especially trains containing wagons equipped with cast iron brake blocks, and is a particularly severe problem during the night time. It has been growing in magnitude due to increased operating speed of freight trains consisting of wagons equipped with cast iron brake blocks. The response from the public authorities and infrastructure managers has so far consisted of rail improvements and noise barriers constructions. However, they do not represent the ultimate solution due to their very local effects, limited sustainability (life-time costs) and long implementation times. 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[3] policy goals of shifting freight to rail. A full impact assessment on rail freight noise reduction was carried out by COWI consultants for the European Commission in May 2014[4], which was further updated by the EC services[5]. 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

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

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

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

	requirements to existing freight wagons is the most effective and efficient solution for rail environmental noise reduction in the EU.
1.5. Context	The exposure of European citizens to harmful noise levels is uneven and vary considerably among the MSs. This is due to different population density, rail network planning and development, local legislation and other drivers. 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. The perception of noise, as one of transport externalities, varies considerably among MSs. Despite a common framework introduced by the Environmental Noise Directive, the level of attention given to railway noise by governments and rail infrastructure managers is likely to continue to vary. 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.
1.6. Scope of the IA	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 analysed in respect of its benefits and costs, but not directly integrated into the B-C analysis, as it would consist of a different policy scenario. Since the 1520 mm network was exempted from the application of TSI and all options under this IA are realized through amendments to NOI TSI, the 1520 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. The period of analysis is 2017-2036 (20 years), being a standard time frame for this type of IA[8].
1.7. Baseline scenario	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, “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.

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[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

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

	For the definition of the baseline, only existing market measures are considered (i.e. DE government-backed retrofitting programme) and their effect on the current fleet is conservatively estimated. 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 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. The impact of the measures in Switzerland and Germany 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.
1.8. Subsidiarity and proportionality	Rail noise problem is limited in scope, not only in terms of specific countries but even in specific areas within these countries. 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 particular, the administrative costs will negatively affect the competitiveness of cross-border rail freight transport, but to a limited extent. 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. The latter option in particular leads to State-aid concerns. EU action in the domain of rail noise reduction can supplement and support 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. It is also understood that the current level of placing newly built wagons, complying with the NOI TSI, on the market, leading to replacement of "noisy" wagons, would not lead to a significant noise reduction in a long-term perspective, since these wagons are currently being removed from the fleet at a low pace (about 1.5 % per year). This is because the operators using those wagons incur higher operation costs raising from additional maintenance costs, what may deter them from investing into new wagons.

	EU action could therefore aim at increasing the pace of the retrofitting in order to obtain socio-economic benefits at an earlier stage, while minimizing 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. **Specific objectives:** - to achieve tangible reduction in noise generated by rail freight in mid-term by accelerating fleet renewal and brake blocks retrofitting. - to maintain the competitiveness of rail freight transport. - to prevent national measures making detrimental effects on freight by rail and to ensure fair market/operating conditions for operators of new and older wagons.
2.2. Link with Railway Indicators	No links with the pilot 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 1.1.2026 Option Ic: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2030 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 1.1.2026 Option IIb: 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 IIc: NOI TSI scope is extended to existing wagons and applicable as from 1.1.2022 where wagons not operated internationally are exempted until 1.1.2030 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 1.1.2022 and to all networks from 1.1.2030. Option IVa: NOI TSI scope is extended to wagons using “quieter routes” as from 1.1.2022 Option IVb: NOI TSI scope is extended to wagons using “quieter routes” as from 1.1.2026 Option IVc: NOI TSI scope is extended to wagons using “quieter routes” as from 1.1.2022 and to all routes from 1.1.2030 (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).
3.2. Description of options	Under the Baseline scenarios, no new regulatory requirements on existing wagons are introduced in the NOI TSI. Existing retrofitting stimulating (financial subsistence) measures applied in different Member States and at the EU level (e.g. CEF) are taken into account. The noise generated by wagons equipped with cast iron brake blocks (noisy wagons) will not significantly diminish. Under **Option I**, all ”noisy” wagons will have to be transformed into “silent” by either retrofitting their brake blocks or be being decommissioned by a given year. 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.

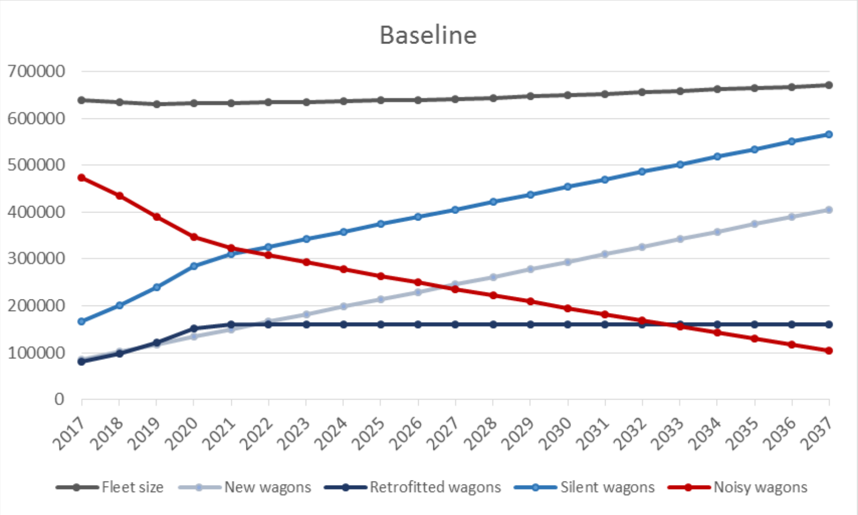
Note that sub-option 2a may not be practically feasible, as it would require retrofitting of additional 200,000 wagons by 2022.

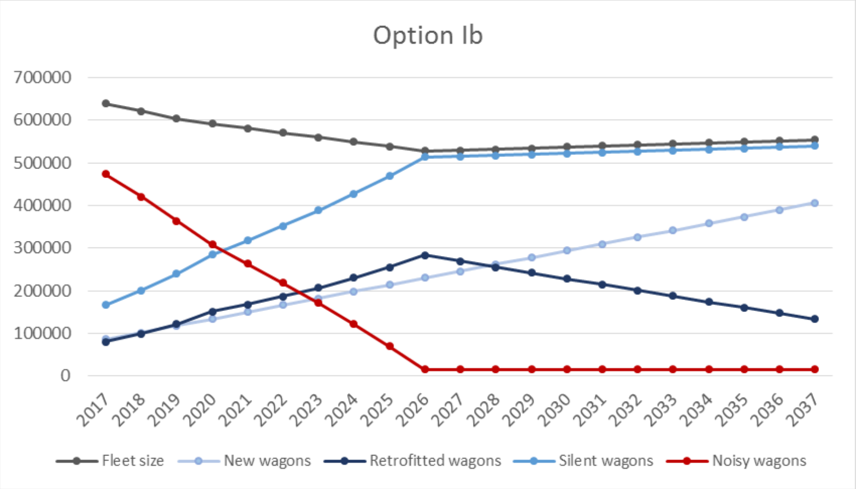
Under **Option III**, gradual application of the regulatory requirements on existing “noisy wagons is foreseen. The “noisy” wagons could continue to be operated in MSs, which do not declare their network “silent”. A ultimate ban (flat application in all MSs) could be later imposed.

Note that legal service of the European Commission advised that this option <u>is not feasible</u> from the regulatory point of view. It is however included in this IA for the sake of comparision 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.

While the Annex I gives a more detailed description of the options, the series of graphs bellows provides an illustration of expected fleet developments for the baseline selected sub-options.





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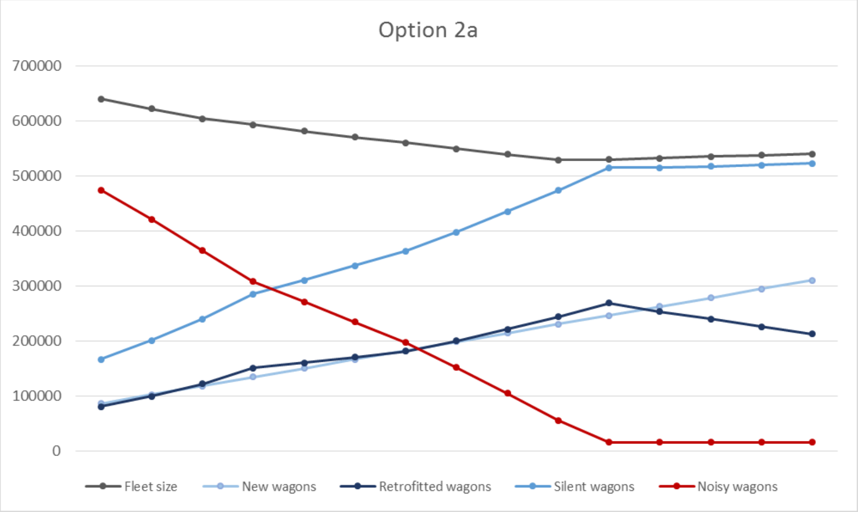

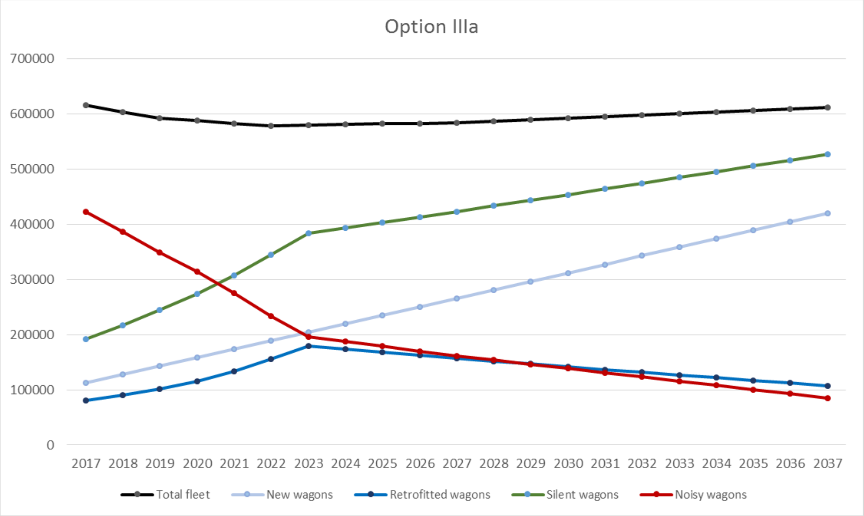

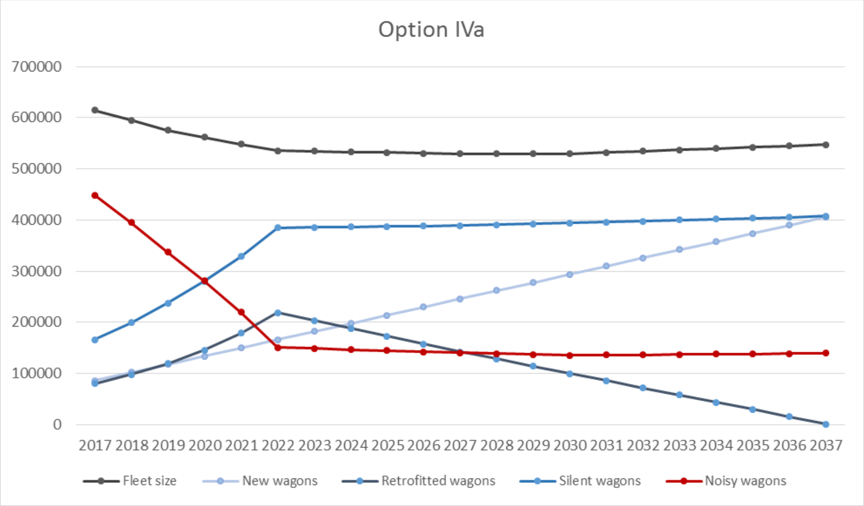

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<td>3.3. Uncertainties/risks</td>
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The start date of the application of NOI TSI on existing wagons depends on the progress in policy discussions and on the application of the legislative process. This is recognized by defining several sub-options for each option, characterized by specific application date.

The development in wagon fleet constitute the main driver for the CBA in this impact assessment. The development in the wagon fleet for the baseline is driven by the response of different countries to German/Swiss
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	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.

4. Impacts of the options

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

Criteria/Option	*0*	*I*	*II*	*III*	*IV*
Accelerate renewal of the fleet	1	4	4	3	3
Accelerate brake blocks retrofitting	1	5	4	3	3
Prevent national measures and ensure fair market	1	5	4	5	5
Optimize implementation strategy	1	2	3	4	5
Overall	**1**	**4**	**3.75**	**3.75**	**4**

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 TF 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	-

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. General Assumptions for the IA

Wagon fleet:

Average theoretical lifetime of a freight wagon is 40 years leading to a natural average annual renewal rate of 2.5%.

The total freight wagon fleet as of 1.1.2017 is estimated to be 640,000 wagons, of which 495,000 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 80,000 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 15,000, 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.

An average theoretical wagon is considered to have the following characteristics: Annual millage 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 (RMMS).

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) 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.

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 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)[9] are taken: 0.124 for cardiovascular

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

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 80% from quieter routes and 20% 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 need of 365,000 silent wagons. (Option I)

We assume that 35% 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 182,000 silent wagons in these countries (of which 70,000 additionally retrofitted).

We assume that 25 % of wagons could be operated exclusively on the routes not depicted as "quieter". This leads to the need of 412,000 silient wagons. (Option II)

Main assumptions are presented here. They are further developed in Annex II.

4.3. Impacts of the options (quantitative analysis)

Category of stakeholder	*Option*	*0*	*I*	*II*	*III*	*IV*
RUs/Keepers	Benefits (M€)	0	0	0	0	0
	Costs (M€)	2147	3765	2720	1964	1868
Citizens	Benefits (M€)	41557	82420	67260	48375	60691
	Costs (M€)	1747	3044	2215	1592	518
Overall	B-C (M€)	41557	82420	67260	48375	60691
	Costs (M€)	3894	6809	4935	3556	3886

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

	0	*I*	*II*	*III*	*IV*
NPV (M€)	33,689	69,564	56,798	17,568	52,778
B/C ratio	1	1.13/1.26/1.38	1.28/1.31/1.40	1.27/1.46	1.47/1.36

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

For furher details, please refer to Annex as follows:

Railway Undertakings and wagon keepers to retrofit and operate retrofitted fleet (costs):

See **Table 5: Cost of retrofitting, € million, year.**

EU citizens exposed to railway noise to benefit from its reduction (benefits):

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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):

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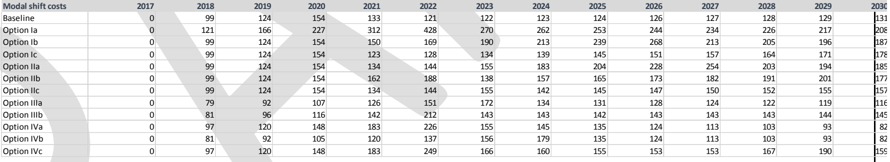

Modal shift costs	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Baseline	0	99	124	154	133	121	122	123	124	126	127	128	129	131
Option Ia	0	121	166	227	312	428	270	262	253	244	234	226	217	20
Option Ib	0	99	124	154	150	169	190	213	239	268	213	205	196	187
Option Ic	0	99	124	154	123	128	134	139	145	151	157	164	171	17
Option IIa	0	99	124	154	134	144	155	183	204	228	254	203	194	185
Option IIb	0	99	124	154	162	188	138	157	165	173	182	191	201	177
Option IIc	0	99	124	154	134	144	155	142	145	147	150	152	155	157
Option IIIa	0	79	92	107	126	151	172	134	131	128	124	122	119	11
Option IIIb	0	81	96	116	142	212	143	143	142	143	143	143	144	145
Option IVa	0	97	120	148	183	226	155	145	135	124	113	103	93	82
Option IVb	0	81	92	105	120	137	156	179	135	124	113	103	93	82
Option IVc	0	97	120	148	183	249	166	160	155	153	153	167	190	15

Table 8: Costs of modal shift in € million for different options

4.4. Uncertainties/risks	The pace of replacement of older “noisy” wagons is also difficult to predict. Market measures are disregarded in this impact assessment and a conservative renewal rate for wagons is assumed. 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. Best up to date estimates are therefore considered here. There is substantial number of “noisy” wagons of specific types, for which the transformation into “silent” wagons incur significantly higher costs. Estimating their real number now and in the future represent a real challenge and assumptions had to be made. The share of wagons with relatively higher retrofitting costs is not equally distributed across the Europe and their number can be significant in some Member States. This may make the case for a Member State specific impact assessment. In spite of substantial research, the methodology has not yet been systematically applied and critically tested. Conservative estimates are therefore thoroughly applied throughout the noise reduction benefits calculation. The method for monetizing costs of environmental noise from rail used in this IA are 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. They provide 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[10]. 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.

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[10] 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	1	4	3.75	3.75	4

All regulatory options (Option I-IV) provide certitude and clarity to the schedule for gradual removal of "noisy" wagons and address the problems to be solved.

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

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

Criteria/Option	*0*	*I*	*II*	*III*	*IV*
Efficiency	1	4	4	4.5	5

All regulatory options have B/C ratio >1 and NPV >0, thus providing a high efficiency. Since the absolute B/C ratios are very similar, the options could be considered as comparable from the efficiency point of view.

5.3. Summary of the comparison

Criteria/Option	*0*	*I*	*II*	*III*	*IV*
Effectiveness	1	4	3.75	3.75	4
Efficiency	1	4	4	4.5	5
Overall rating	**1**	**4**	**4-**	**4+**	**4.5**

Relying on the wagon fleet renewal driven purely by market forces is likely to bring a very limited benefits in the years towards 2020 an even more limited beyond. This is because with the renewal rate of 2.5%, the entire fleet will become silent only towards the year 2050. At the same time, the national initiatives may bring an important contribution to the retrofitting of the fleet.

However, the choice of the year by which wagons must comply with NOI TSI requirements influences the B/C ratio as well. The options Ic, IIIb, IVa yield the highest B/C ratio as they require less wagons to be retrofitted and at the same time they gather noise reduction benefits on networks where many citizens are exposed to railway noise.

Since the Net benefits of different options are rather comparable (with absolute B/C ratio being relatively close to each other), the effectiveness criteria should inform the final choise of the option. Option III and IV score higher in terms of effectiveness than Option I and II.

Some sub-options with a later application year show higher efficiency (B/C ratio) than the starting suboption (typically 2022 application year). They however have lower effectiveness scores. The final choice should therefore be also driven by the feasibility criteria.

5.4. Preferred option(s)	At the level of Union and from purely economic perspective, the preferred option is Option III or IV. They smoothen the financial impact on the railway sector, while at the same time, providing substantial noise reduction benefits within a mid-term timeframe. Among the assessed sub-options, the sub-options IVa can be recommended on the basis of this Impact Assessment. The option IVb (with the second flat application deadline) provides limited incremental benefits, while bringing with it substantial additional costs (to retrofit remaining "noisy" wagons. Also, while the later application date (e.g. 2028,2030) brings along higher efficiency, it does reduce the effectiveness. Thus the earlier application of the NOI TSI should be priviledged.
5.5. Further work required	CBA analysis may need to be carried out in case of countries requesting a special case. This in response to the legal requirement to provide economic justification.

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	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.

Annex I: Developments in wagon fleet

Background and scope

Estimations of the current wagon fleet and of its development is based on information available in National Vehicle Registers (NVRs) and in the 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 1-2). Comprehensive trend lines are showed together with the simplified trend line for options (see Appendix to Annex I).

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

Above estimations of the wagon fleet development based on information available in National Vehicle Registers (NVRs) and in the Eurostat database.

Development of the total wagon fleet

The number of wagons as of 1.1.2017 has been determined for all countries based on NVR and Eurostat data, complemented by enquiries to selected MSs (NSAs).

As per 1.1.2017, the wagon fleet for the IA countries is estimated to be 640,000 wagons. We assume that this will slightly decrease in the next ten years and almost flatten afterwards, under the baseline scenario. In case of NOI TSI scope revision, 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 likely to play a role for EU wagon fleet in the future (see Appendix to Annex I).

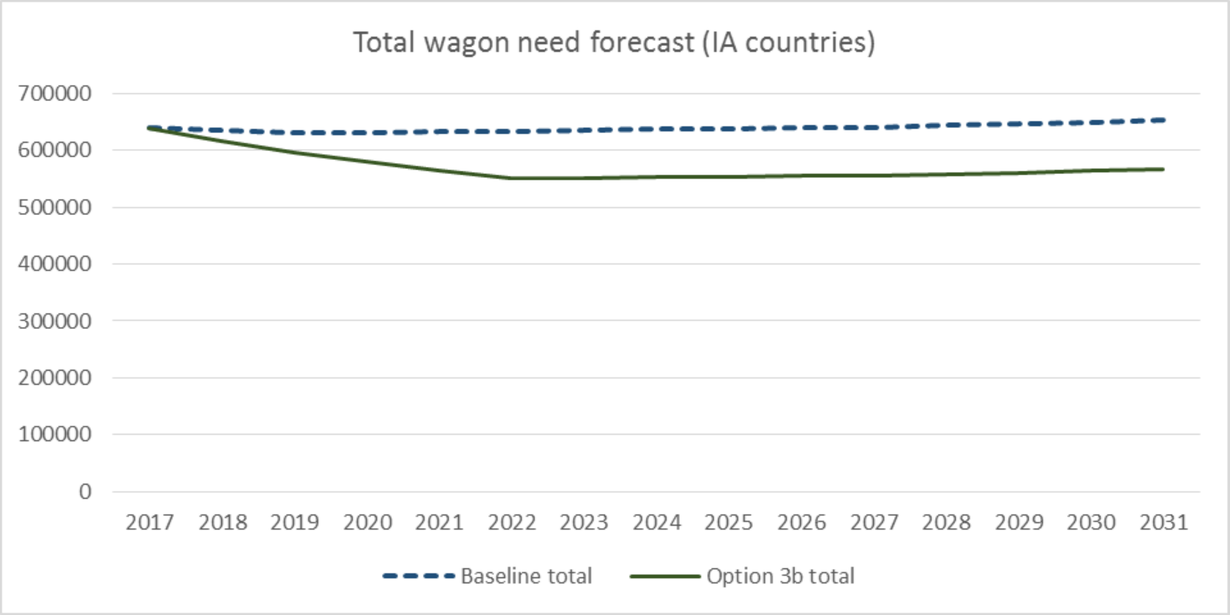

Figure 1: Total wagon fleet forecast for baseline and option 3b

Both forecast trend lines (baseline, options) can be simplified as follows: For baseline, the total number of wagons decreases from 640,000 wagons in 2017 to 635,000 wagons in 2022. For all options except option IIIa, the total number of wagons decreases from 640,000 to under 550,000 by a first ban. It then remains constant (see Appendix to Annex I). The model used for the B/C analysis however relies on the comprehensive forecast trends.

Fleet development for baseline

Renewal rates

We consider that only wagons with CI BB are subject to renewal, at an annual renewal rate of 2.5%. (This corresponds to the renewal rate needed for wagon with an average lifecycle of 40 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 2035).

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.

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 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.

As per information provided by the German Transport Ministry (BmVi), as of May 2016, 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.

Although we may expect the number of applications to increase, we consider this figure as the minimum retrofitting figure for the EU-28 by 2020, even under the assumption of no change to the current NOI TSI.

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

We assume the number of retrofitted wagons to be 80,000. This number should increase to 150,750 to by 1.1.2020, due to the drivers described above.

(We do not consider the impact of ongoing/planned NDTAC, as they constitute market measures and do not fall under the scope of this impact assessment.)

Above estimates lead to the following fleet development for the baseline scenario:

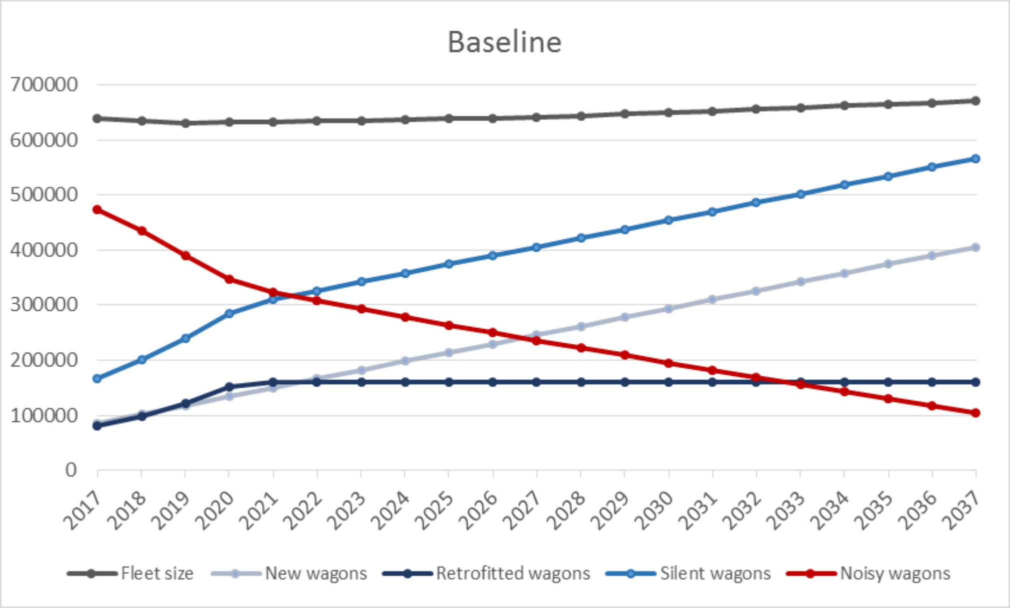

Figure 2: Wagon fleet development for the baseline

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 2.5%. 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 615,000 x 0.025 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:

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

N_y is a number of retrofitted wagons in year Y 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 80,000 in 2016 to 370,000 in 2022. Applying the formula above: n=(370/80)^(1/(2022-2016))=0.36. So, the number of retrofitted wagons will have to increase by 36% each year between 2016 and 2022.

Exemptions from retrofitting obligation

A small number of wagons is expected to be exempted from the regulatory requirements for retrofitting due to their low mileage and specific use. Notably, the maintenance vehicles (registered as wagons) and heritage/nostalgic wagons shall be excluded. We do not assume wagons to be exempted from retrofitting obligation due to safety or other concerns (e.g. wagon fleet in Scandinavian countries).

Furthermore, not all existing wagons will be retrofitted due to the absence of a technical solution for retrofitting (e.g. wagons with small wheel diameter). We assume that no technical solution is found in coming years, specifically until the ban year.

The total number of wagons assumed to be exempted from the obligation to retrofit is 15,000.

The expected development in the number of different types of wagons for Option IIIa and Option IIIb is shown in Figure 3 and Figure 4. The total number of wagons decreases only slightly in Option IIIa, since the optimization/rationalization takes only place in a few countries with the ban.

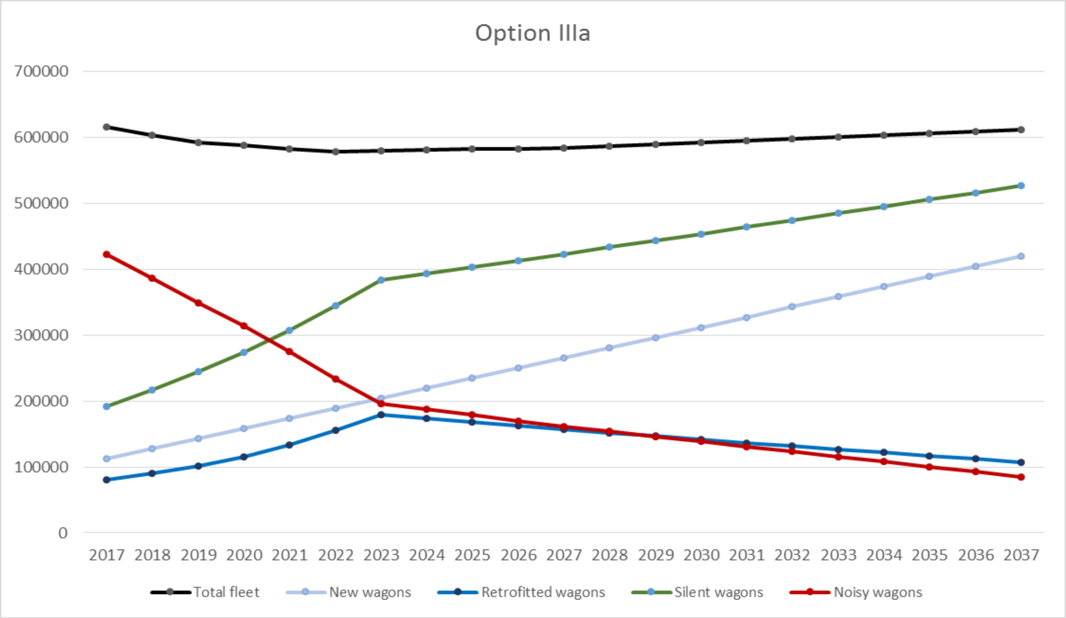

Figure 3: Total wagon fleet forecast for option IIIa

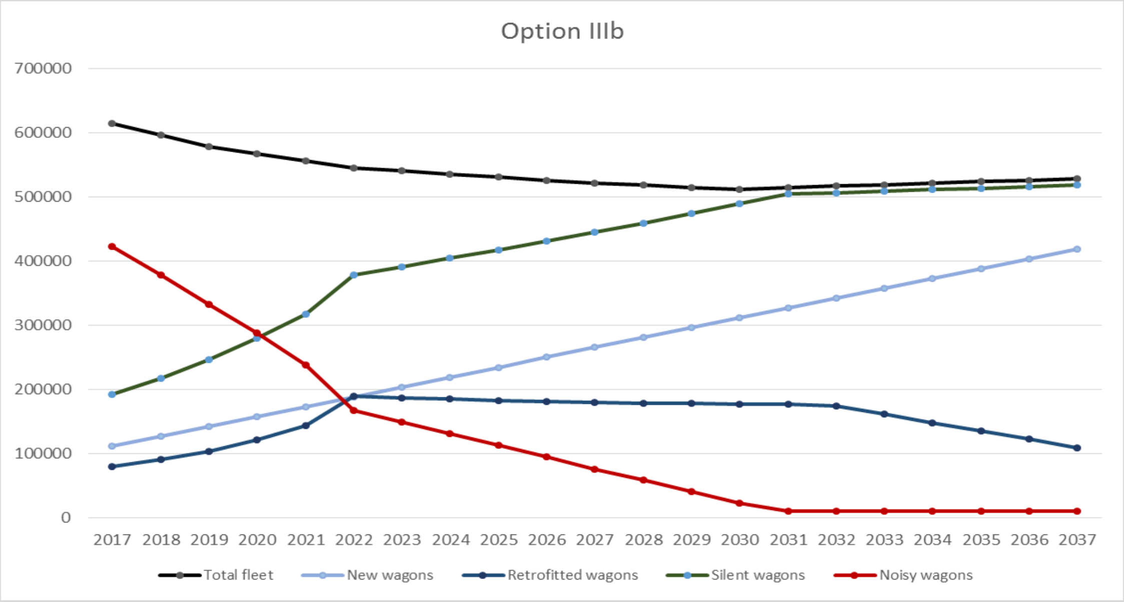

Figure 4: Total wagon fleet forecast for option IIIb

Appendix to Annex I: Current wagon fleet (wagon fleet as of 04.04.2017)

Wagons per MS of registration	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV
Total wagons	23345	13145	16915	2274		43520	366	20849	13454	77678	165363	3182	3755	254	25365	11888
NOI-TSI compliant New wagons	*4511*	*2312*	*568*	*183*		*7227*	*225*	*0*	*4167*	*5558*	*21300*	*5413*	*911*	*0*	*2783*	*0*
Retrofitted wagons	*2000*	*0*	*0*	*200*		*0*	*0*	*0*	*0*	*3000*	*34000*	*0*	*0*	*100*	*0*	*0*
Total NOI-TSI compliant	6511	2312	568	383		7227	225	0	4167	8558	55300	5413	911	100	2783	0
Tyred wheel wagons			*12500*													
SS-wagons with kink-valves															*12000*	
Other exempted wagons																
Total Exempted wagons																

Wagons per MS of registration	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK	CH	NO	IA countries
Total wagons	14828	3610		21226	83500	3123	30000	28470	3230	20639	11000	18246	17201	1623	**638356**
NOI-TSI compliant New wagons	*0*	*1410*		*7500*	*1500*	*929*	*3614*	*5477*	*226*	*792*	*931*	*2467*	*5450*	*516*	***85947***
Retrofitted wagons	*0*	*0*		*1500*	*0*	*2150*	*0*	*0*	*0*	*15000*	*0*	*13000*	*9000*	*0*	***79950***
Total NOI-TSI compliant	0	1410		9000	2750	3079	3614	5477	226	15792	931	15467	14450	516	**165897**
Tyred wheel wagons					*61000*		*22200*								
SS-wagons with kink-valves															
Other exempted wagons					*1350*										
Total Exempted wagons					62450										

The sources for the total estimate:

NVRs (NSAs)	Query into European/National Vehicle Register by ERA on 04.04.2017 (data provided by National safety authorities)
NSO (ESTAT)	Query into Eurobase by ERA in 03.04.2017 (data provided by National statistical offices)
Other sources (ERA)	Published national reports (IM, operators, regulators, …)
NSA	Ad hoc enquiry by the NSA.

The number of TSI compliant wagons was estimated from two figures available in national registers: Wagons authorized after 08.08.2006 and wagons manufactured after 1.1.2006, complemented with other sources.

The total number of wagons in IA countries is 640,000. We assume that 15,000 of them are wagons that are likely to be excluded from the NOI TSI application. This leads to a total of 623,000 wagons by 1.1.2017 in IA countries as a starting point for the IA.

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*[11]*, 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 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.

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[11] *(*) 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.*

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[12]*. 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.*

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[12] McKinsey 2014: Getting freight back on track

Annex II: Cost-benefit analysis of options

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 cost estimates below represent best to date Agency knowledge, with figures coming from the railway industry. The low and high estimates will be added later following additional input from the industry.

Average mileage of wagons

Annual number of freight train kilometres for EU-28+NO+CH is 820,000[13] km. Assuming the average number of wagons per train to be 18 leads to annual millage of an average wagon of 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 4 axles, however many wagons have a 2 axles configuration. While their share is difficult to establish, the analysis of data records in the RSRD[2] suggests that on average, there are 4 axles per wagon in practice. We use this estimate in the calculation of retrofitting costs. The configuration 2xBgu is considered, meaning 4 BB per wheel on 8 wheels wagon (32 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 7 years. Therefore, a pro-rata factor of 0.5 is applied to certain common items in table below.

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[13] ERAIL-CSI database for year 2014, reporting by NSAs under RSD, Annex I

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 costs	Material - wheelset	2,600	4	0.5	5,200
	Material - brake cylinder/ventil	675	2	1	1,350
	Work – wheelset replacement	250	4	0.5	500
	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 (€)					**8,986**
Special wagon - tyred wheels - one-off additional costs (€)					**12,100**
S-type wagon - costs per km over remaining lifetime (€/km)					0,00195
SS-type wagon - ss - costs per km over remaining lifetime (€/km)					0,00798
Special wagon - tyred wheels - costs per km over remaining lifetime (€/km)					0,01405

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

Table 1: 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.

Life-cycle (maintenance) costs

Wagon/cost type	**Item**	Unit cost (€)			Interval (km)		Total costs (€)		
		CI BB	**LL BB**	**Quantity**	**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 (€)									**0,02150 €**

Table 2: 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

Table 3: Additional life-cycle cost estimates provided by stakeholders

CER cost values used in the sensitivity analysis

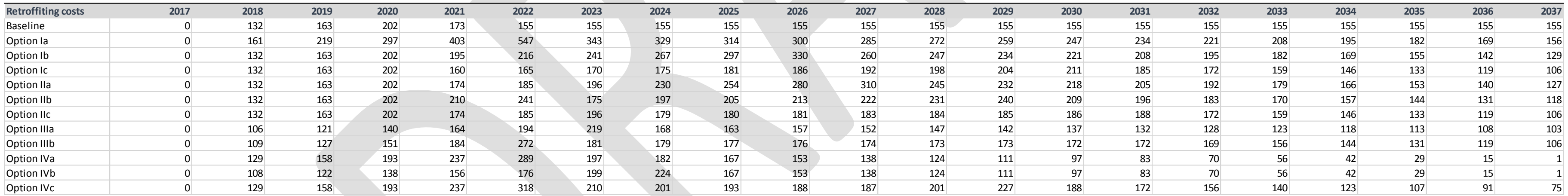
We estimate from available national data the following wagon type distribution among wagons to be retrofitted over the entire period under assessment (Table 4):

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

Table 4: Assumed wagon type distribution in the IA countries wagon fleet

There is estimated 80,000 tyred wheels wagon in IA countries among 414,000 wagons that need to be retrofitted. We assume that only 60,000 will be retrofitted. This leads to a relative share of 14%. For 40,000 SS-type wagons, we assume that all of them will be retrofitted, leading to their relative share among wagons for retrofit of 9%.

Table 5 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	132	163	202	173	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Option Ia	0	161	219	297	403	547	343	329	314	300	285	272	259	247	234	221	208	195	182	169	156
Option Ib	0	132	163	202	195	216	241	267	297	330	260	247	234	221	208	195	182	169	155	142	129
Option Ic	0	132	163	202	160	165	170	175	181	186	192	198	204	211	185	172	159	146	133	119	106
Option IIa	0	132	163	202	174	185	196	230	254	280	310	245	232	218	205	192	179	166	153	140	127
Option IIb	0	132	163	202	210	241	175	197	205	213	222	231	240	209	196	183	170	157	144	131	118
Option IIc	0	132	163	202	174	185	196	179	180	181	183	184	185	186	188	172	159	146	133	119	106
Option IIIa	0	106	121	140	164	194	219	168	163	157	152	147	142	137	132	128	123	118	113	108	103
Option IIIb	0	109	127	151	184	272	181	179	177	176	174	173	173	172	172	169	156	144	131	119	106
Option IVa	0	129	158	193	237	289	197	182	167	153	138	124	111	97	83	70	56	42	29	15	1
Option IVb	0	108	122	138	156	176	199	224	167	153	138	124	111	97	83	70	56	42	29	15	1
Option IVc	0	129	158	193	237	318	210	201	193	188	187	201	227	188	172	156	140	123	107	91	75

Table 5: Cost of retrofitting, € million, year

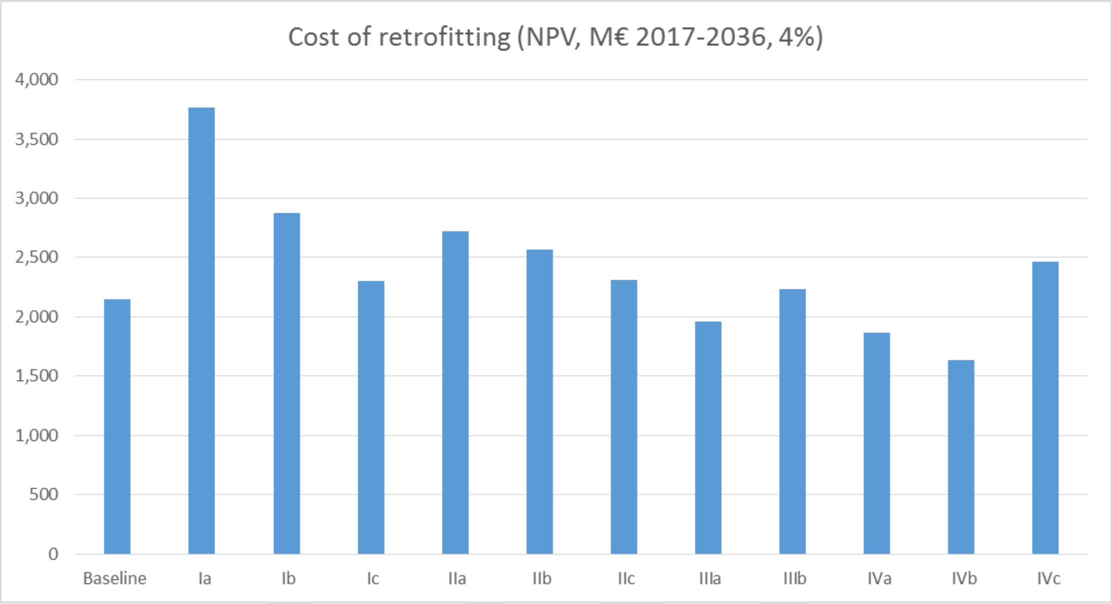


Figure 5: Net present value (NPV) of retrofitting costs for options and baseline (in € million)

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.

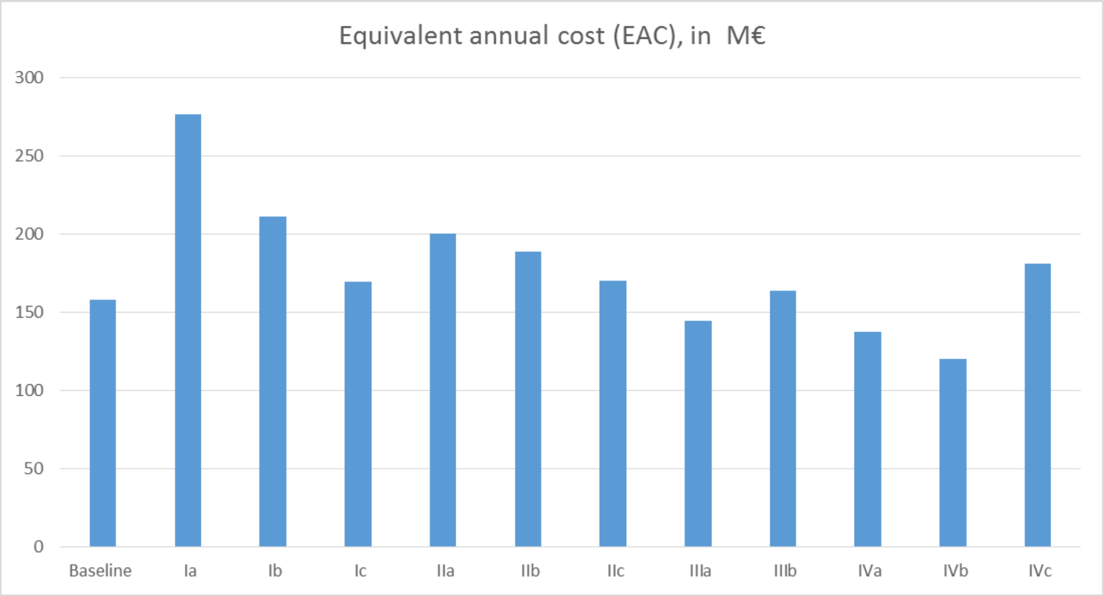


Figure 6: Equivalent annual costs (EAC) in M€

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[14];
- negative effects on human health, e.g. risk of cardiovascular diseases (heart and blood circulation[15];
- property value lose

The recommended method for monetization is stated preferences for a direct measurement of WTA compensation or 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[16].

We apply the stated preference methodology (i.e. WTP for reducing annoyance and health damages) as proposed by the WHO[17] (economic burden of disease method).

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 desease (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):

$YLL = N \cdot L$

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

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

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

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

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.*

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[18]. (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[19]. 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)[20].

For cardiovascular disease:

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

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, becase 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:

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[18] Reported data on noise exposure covered by Directive 2002/49/EC, available on EEA website

[19] European Environmental Agency (2014): Noise in Europe 2014

[20] Burden of disease from environmental noise, Quantification of healthy life years lost in Europe, WHO and JRC, 2011

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

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):

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

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

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[21]. 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[22] 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.

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[21] 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)

[22] 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

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[23] (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 calculate the economic cost of railway noise. These values were used in the latest EC assessment of air pollution costs in Europe[24].

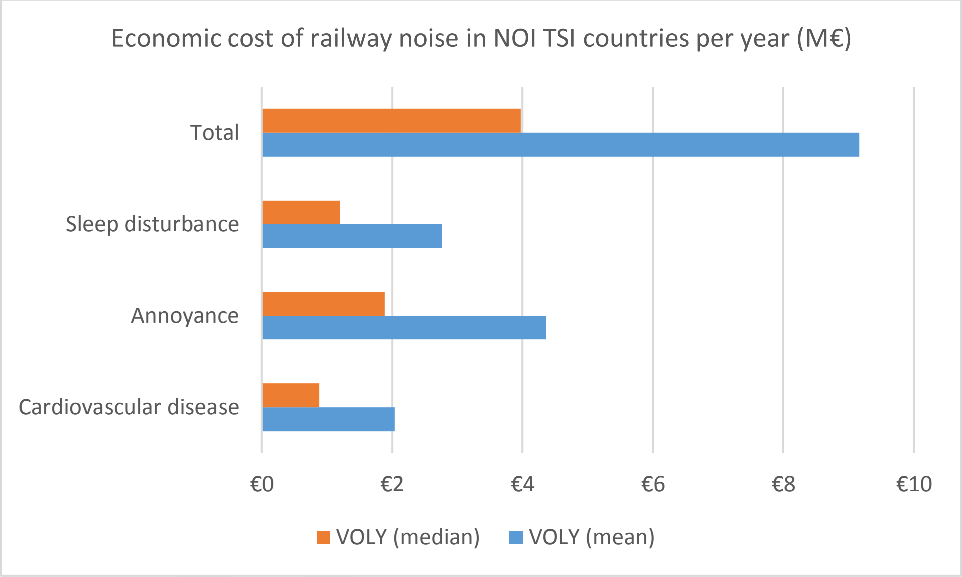

Figure 7: Value of railway noise in NOI TSI countries (MEUR/year)

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

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

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

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.

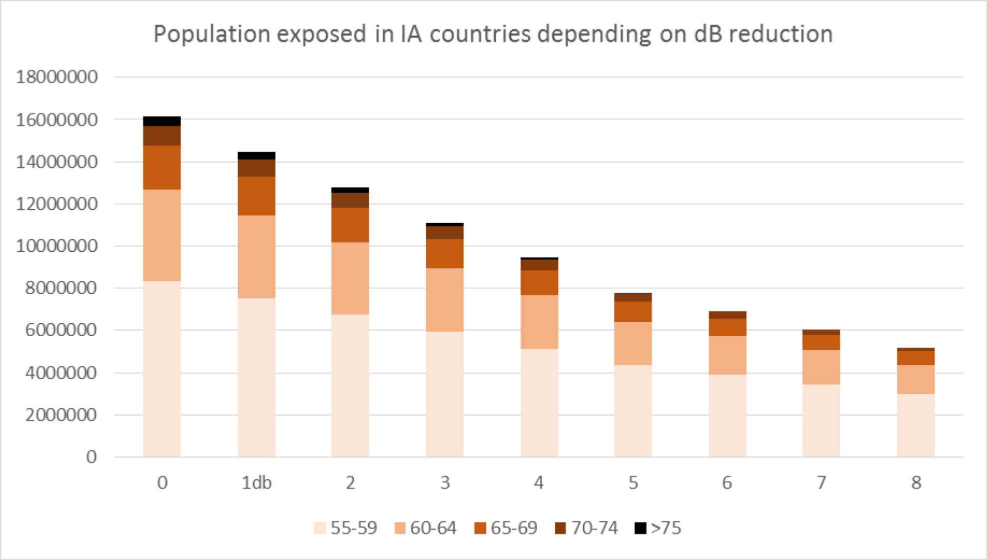

Figure 8: Population exposed to noise above 55dB in IA countries resulting from different noise reduction

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	1774	2070	2218	2513	2809	2957	3252	3548	3844	4140	4287	4583	5027	5322	5618	5836	6047
Option Ia	0	591	1331	2661	4731	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451
Option Ib	0	444	1035	1626	2365	3105	3992	5174	6257	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451	7451
Option Ic	0	444	1035	1626	2070	2513	2957	3548	4140	4879	5766	6187	6749	7451	7451	7451	7451	7451	7451	7451	7451
Option IIa	0	444	1035	1626	2218	2809	3400	4435	5618	6538	7451	7381	7381	7381	7381	7381	7381	7381	7381	7381	7381
Option IIb	0	444	1035	1626	2365	3252	3400	3992	4731	5618	6257	6889	7451	7451	7451	7451	7451	7451	7451	7451	7451
Option IIc	0	444	1035	1626	2070	2661	3252	3844	4287	5027	5618	6117	7451	7451	7451	7451	7451	7451	7451	7451	7451
Option IIIa	0	480	997	1687	2308	2996	3579	3752	3838	4011	4097	4270	4443	4529	4702	4874	5047	5220	5392	5565	5738
Option IIIb	0	480	1083	1773	2567	3798	4057	4402	4747	5093	5524	6042	6349	6699	7050	7050	7050	7050	7050	7050	7050
Option IVa	0	591	1301	2365	3903	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369
Option IVb	0	473	1064	1656	2602	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369	5369
Option IVc	0	591	1301	2365	3903	5488	5547	5635	5754	5902	6168	6582	7199	7269	7269	7269	7269	7269	7269	7269	7269

Table 6: Net benefit from reduced noise (M€/year)

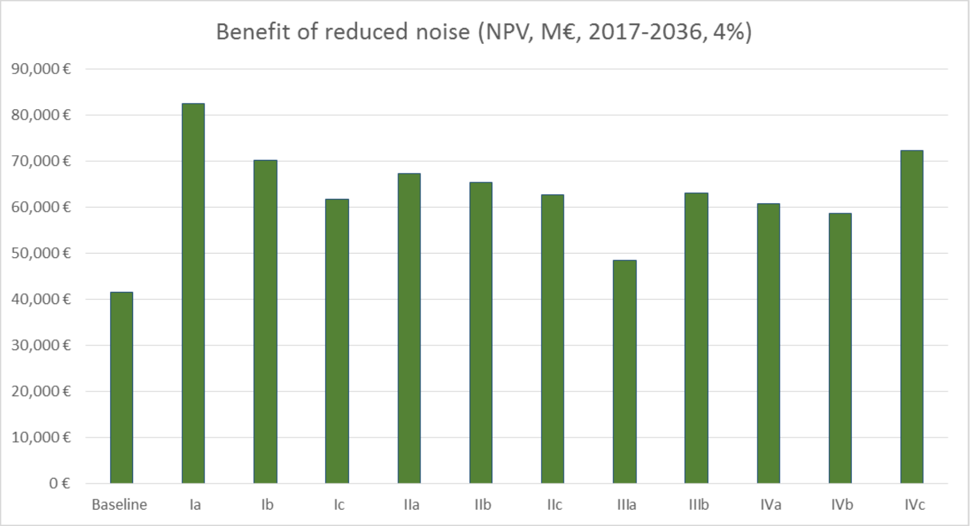

Figure 9: Net present value (NPV) of noise reduction benefits for options and baseline (in € million)

Estimation of the impact of retrofitting on modal shift

The additional retrofitting 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[25] and external costs estimates from CE Delft study[26]. 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 retrived 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[27].

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 tonne-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

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

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

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

donating mode relative to the receiving mode, based on their respective absolute percentage increases C_d and C_r.

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 2016 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**		**2016**	
	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 7: 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 0.50%.

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

Modal shift costs	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	99	124	154	133	121	122	123	124	126	127	128	129	131	132	133	135	136	137	139	140
Option Ia	0	121	166	227	312	428	270	262	253	244	234	226	217	208	199	190	181	171	161	151	141
Option Ib	0	99	124	154	150	169	190	213	239	268	213	205	196	187	177	168	158	148	138	128	117
Option Ic	0	99	124	154	123	128	134	139	145	151	157	164	171	178	158	148	138	128	118	107	96
Option IIa	0	99	124	154	134	144	155	183	204	228	254	203	194	185	175	166	156	146	136	125	115
Option IIb	0	99	124	154	162	188	138	157	165	173	182	191	201	177	167	158	148	138	128	117	106
Option IIc	0	99	124	154	134	144	155	142	145	147	150	152	155	157	160	148	138	128	118	107	96
Option IIIa	0	79	92	107	126	151	172	134	131	128	124	122	119	116	113	110	107	104	100	97	94
Option IIIb	0	81	96	116	142	212	143	143	142	143	143	143	144	145	147	146	136	126	116	106	96
Option IVa	0	97	120	148	183	226	155	145	135	124	113	103	93	82	71	60	49	37	25	14	1
Option IVb	0	81	92	105	120	137	156	179	135	124	113	103	93	82	71	60	49	37	25	14	1
Option IVc	0	97	120	148	183	249	166	160	155	153	153	167	190	159	147	134	121	108	95	82	68

Table 8.

Modal shift costs	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Baseline	0	99	124	154	133	121	122	123	124	126	127	128	129	131	132	133	135	136	137	139	140
Option Ia	0	121	166	227	312	428	270	262	253	244	234	226	217	208	199	190	181	171	161	151	141
Option Ib	0	99	124	154	150	169	190	213	239	268	213	205	196	187	177	168	158	148	138	128	117
Option Ic	0	99	124	154	123	128	134	139	145	151	157	164	171	178	158	148	138	128	118	107	96
Option IIa	0	99	124	154	134	144	155	183	204	228	254	203	194	185	175	166	156	146	136	125	115
Option IIb	0	99	124	154	162	188	138	157	165	173	182	191	201	177	167	158	148	138	128	117	106
Option IIc	0	99	124	154	134	144	155	142	145	147	150	152	155	157	160	148	138	128	118	107	96
Option IIIa	0	79	92	107	126	151	172	134	131	128	124	122	119	116	113	110	107	104	100	97	94
Option IIIb	0	81	96	116	142	212	143	143	142	143	143	143	144	145	147	146	136	126	116	106	96
Option IVa	0	97	120	148	183	226	155	145	135	124	113	103	93	82	71	60	49	37	25	14	1
Option IVb	0	81	92	105	120	137	156	179	135	124	113	103	93	82	71	60	49	37	25	14	1
Option IVc	0	97	120	148	183	249	166	160	155	153	153	167	190	159	147	134	121	108	95	82	68

Table 8: Costs of modal shift in € million for different options

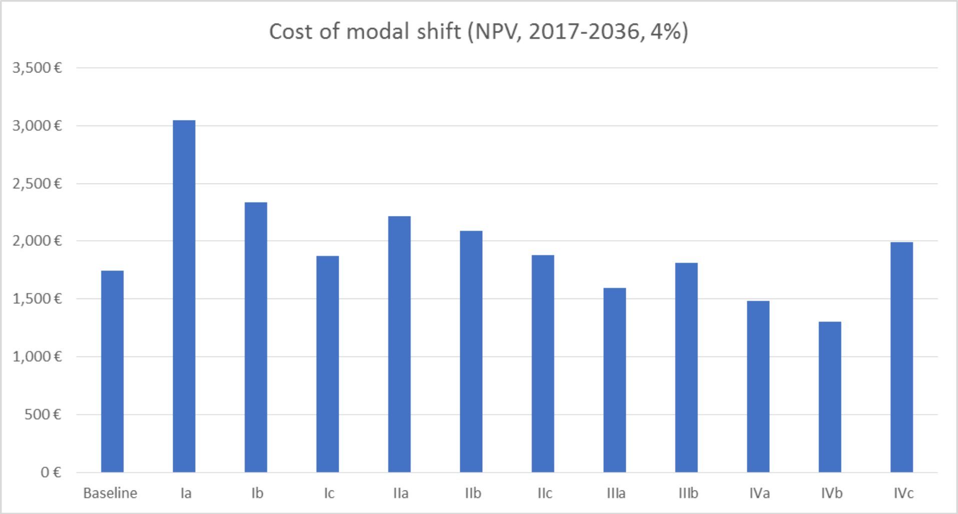

Figure 10: Net present value (NPV) of the cost of modal shift in M€

Efficiency assessment (B/C ratios)

The **total costs** considered consists of costs of retrofitting and of the costs of resulting modal shift.

The **total benefits** considered equal the value of reduced noise.

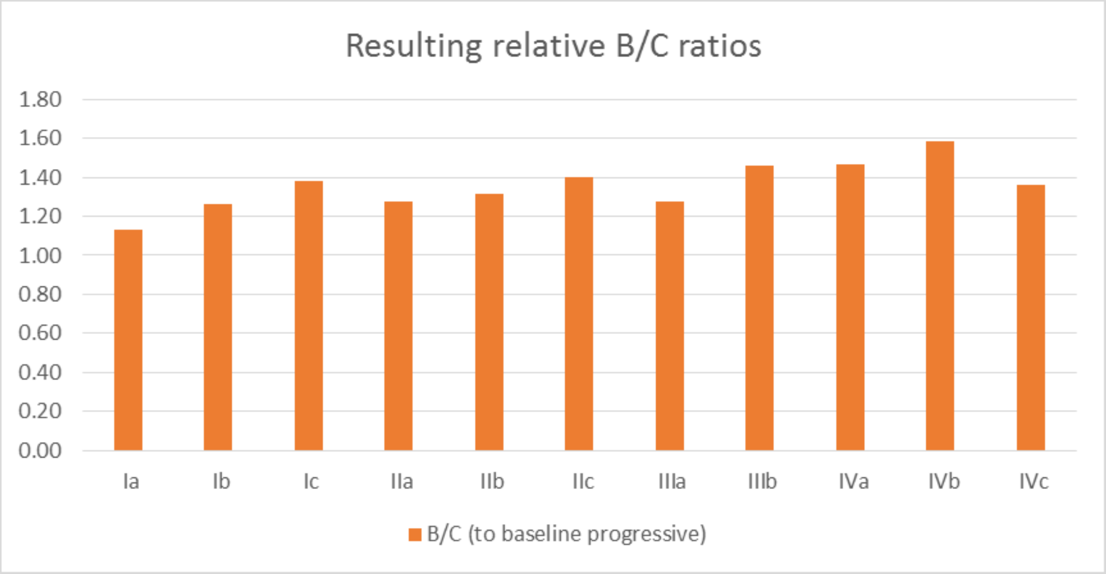

Figure 11: Relative B/C ratios for all options

All options have a relative B/C ratio higher than one meaning that the options is economically beneficial. A gradual implementation of ban of noisy wagons in time leads to higher ratios. However, the difference is relatively small in case of options 2 (national/international wagons). The options with the highest B/C are options 2a and 3b.

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. In addition, the switching values will be determined.

Sensitivity analysis will be carried out in the next stage.

The min/max values provided for the input variables will be further tested to determine B/C ratio after adjustments for min/max values.

For example, for the retrofitting costs, the following min/max values will be tested.

One-off costs (provided by stakeholders, to be critically analyzed)		min	Middle	max
Costs per wagon	S-type wagon wagon - one-off additional costs (€)	€ 1,639	€ 1,994	€ 2,180
	SS-type wagon - one-off additional costs (€)	€ 3,681	€ 4,594	€ 5,080
	Tyred wheels wagon - one-off additional costs (€)	€ 13,039	€ 16,194	€ 19,180
Costs per wagon	S-type wagon - costs per km over remaining lifetime (€/km)	0.0018	0.0022	0.0024
	SS-type wagon - costs per km over remaining lifetime (€/km)	0.0041	0.0051	0.0056
	Tyred wheels wagon -costs per km over remaining lifetime (€/km)	0.0145	0.0180	0.0213

Life-cycle costs (provided by stakeholders, to be critically analyzed)	min	middle	max
Life-cycle additional costs per wagon and year (€)	€ 644	€ 1,013	€ 2,464
Life-cycle additional costs per wagon per km (€)	€ 0.014	€ 0.023	€ 0.055

These could then be used to re-calculate the total costs of retrofitting for different input values is shown below, expressed as NPV and EAC values.

NPV	ERA	CER AVG	CER MAX	CER MIN	EAC	ERA	CER AVG	CER MAX	CER MIN
Baseline conservative	2 376 €	2 599 €	5 667 €	1 671 €		160	175	381	112
Baseline dynamic	2 534 €	2 772 €	6 043 €	1 781 €		170	186	406	120
Option 1a	3 636 €	3 977 €	8 672 €	2 556 €		244	267	583	172
Option 1b	2 882 €	3 153 €	6 874 €	2 026 €		194	212	462	136
Option 2a	2 868 €	3 137 €	6 839 €	2 016 €		193	211	460	136
Option 2b	2 573 €	2 815 €	6 137 €	1 809 €		173	189	413	122
Option 2c	2 441 €	2 670 €	5 821 €	1 716 €		164	179	391	115
Option 3a	2 400 €	2 626 €	5 724 €	1 687 €		161	176	385	113
Option 3b	2 570 €	2 811 €	6 129 €	1 807 €		173	189	412	121

Annex III: Estimation of the impact on lineside acoustic walls

Noise barriers have been used in the past to reduce noise from land transport systems and are widely used for mitigating railway noise in mainland Europe. In the general case of trying to protect people in low rise dwellings next to railways, a 10 dB(A) reduction in rolling noise can be achieved by a reflective barrier approximately 2m high relative to railhead level. For higher barriers the upper limit for the effectiveness of a reflective barrier is approximately 15 dB(A). Absorptive barriers are more effective[28]. We could therefore assume that the noise reduction achieved with 2m high noise barriers is fully comparable to the reduction achieved with brake blocks retrofitting.

In only seven networks, overall more than 3,000 km of barriers with an average height of between 2 and 3 meters have been installed. Another 500 km are expected to be installed in the next 10 years[29] .

For 10 national networks, estimated €1.7 billion is planned to be spent over the next 10 years. Assuming the average investment cost of €0.85 million/km noise barrier, this translates into 200 km of one side noise barrier per year in those 10 countries.

Millions	2000-2015	2015-2025	TOTAL
AT	€ 402	€ 75	€ 477
CH	€ 830	€ 230	€ 1.060
CZ	€ 62	*€ 50e*	€ 62
DE	€ 1.941	€ 487	€ 2.428
ES	€ 124	€ 18	€ 142
HU	€ 27	€ 25	€ 52
NL	€ -	€ 453	€ 453
PL	€ 99	*€ 200e*	€ 99
SE	€ 30	€ 30	€ 60
FR	€ 140	€ 129	€ 269

Table 9: Noise barriers investment in selected MSs (PANTEIA and ProRail 2016)

The total length of the rail network in the sample of 10 countries is 134,349 km, which represent 59% of the total length of railway lines in IA countries. Extrapolating the investment plans above to all IA countries, we may expect 336 km of noise barriers for costs of € 285 million to be built in IA countries each year over the next ten years.

This compares to €100-200 million spent annually in IA countries for retrofitting (under options 1-3). This means that 50% of financial resources nowadays earmarked for noise barriers would pay for the retrofitting, which delivers higher noise reduction benefits, as the whole population is positively affected.

It could be recommended to redirect funds available under EU financing programmes and used for noise barriers constructions into brake blocks retrofitting programmes.

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[28] Brian Hemsworth, Noise Consultants LLP, Development of action plans for railways, UIC 2008

[29] Railway noise in Europe, State of the art report 2016, Paul de Vos et al. for UIC, UIC 2016

Estimation of the impact of retrofitting on operating costs

The extension of scope of the NOI TSI on existing wagons is expected to result in the reduction of the total wagon fleet, as described in the chapter on fleet development. It is notably expected that underused older wagons will be scrapped.

This represent certain operating savings, since each wagon, runs maintenance costs independent of its actual use[30]. This savings could be higher than an increase in operating costs of wagons that will have to assure higher mileage (to transport the same volume of goods). This under the assumption that the average annual costs of maintenance is lower for maintenance based on mileage requirements compared to maintenance based on periodicity requirements.

At the same time the residual value of replaced wagons is marginal (residual value of a wagon older than 25 years is considered to be zero considering the widely applied 4% annual discount rate[31].

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[30] Appendix 10 to GCU, ver. 1.1.2016 defining maximum maintenance cycle of 6 years regardless millage

[31] Appendix 5 to GCU, ver. 1.1.2016 defining the annual discount rate of 4% p.a.

Annex IV: 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[32]
	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

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[32] 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 V: 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

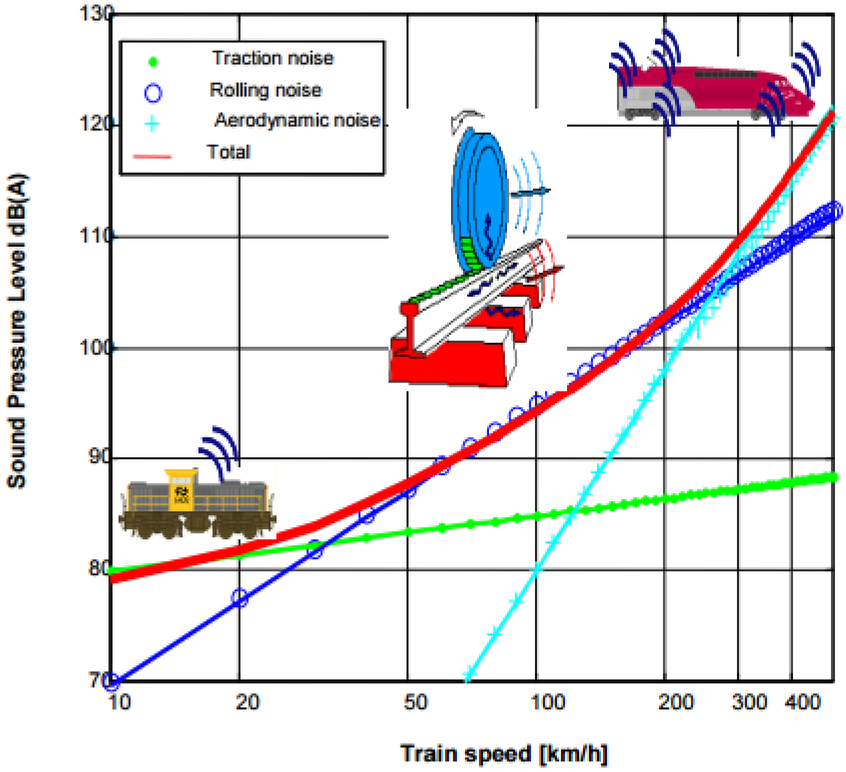
Disability-Adjusted Life Year (DALY)	Measure of overall disease burden, expressed as the number of years lost due to ill-health, disability or early death.
Net Present Value (NPV)	Difference between the present value of cash inflows and the present value of cash outflows.

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

Annex VI: Key concepts

Rolling noise

Figure below shows the typical importance of each of the main types of noise as a function of speed, although the absolute and relative noise levels are only indicative and will vary with train design[33]. It does show the potential for power equipment noise to be dominant at low train speeds, for rolling noise to be the main source at speeds from 50 km/h to 300 km/h and for aerodynamic noise to become significant at higher speeds. The latest publications about the contribution of the rolling noise and the aerodynamic noise show that the contribution of the aerodynamic noise is not as high as previously assumed and that the reduction of the global pass-by noise must combine actions on the both sources.



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[33] Gautier, Poisson and Letourneaux: "Noise Sources for high speed trains: a review of results in the TGV case" Paper to IWRN Munich, September 2007