Explanatory Note to Decision 2014/024/R

Fuel tank flammability reduction of already certified large aeroplanes

RMT.0075 (26.008) — 21.7.2014

Executive Summary

This Decision is related to fuel tank flammability requirements for already certified large aeroplanes.

CS-25 requires the installation of Flammability Reduction Means (FRM) in large aeroplanes with a high flammability exposure. These requirements are contained in Appendix M of CS-25, and are, therefore, applicable to new large aeroplane types for which the application for TC was made after 6 July 2009 and to some significant changes to older types. New deliveries of already certified types are also equipped with FRM ('production cut-in').

The specific objective of rulemaking task RMT.0075 (26.008) was to consider further improving the protection of occupants on board large aeroplanes operated in commercial air transport (CAT) by reducing the risk of fuel tank explosion. This improvement could be reached by applying the same standards that are applicable to new types also to the existing in-service fleet ('retrofit').

The Regulatory Impact Assessment (RIA) compared the option for a mandatory retrofit to the default option of 'no regulatory change'. The 'no regulatory change' option would create no additional rules. Since CS-25 was amended several years ago and the production cut-in is effective, the progressive phase-out of 'old' aeroplanes would gradually remove the risk from the fleet.

The RIA also showed that a mandatory retrofit of FRM would have a limited safety benefit. On the other hand, the economic burden ensuing from such a retrofit is significant. Therefore, the retrofit is considered disproportionate and not cost-effective in relation to the possible safety benefit.

In conclusion, this Decision provides no amendment to existing rules nor additional rules, in accordance with the results of the RIA, and terminates the rulemaking action related to this subject.

Applicability		**Process map**	
Affected regulations and decisions:	None, as this Decision terminates task RMT.0075, (26.008)	Concept Paper:	Yes
Affected stakeholders:	EU operators of Large Aeroplanes used for Commercial Air Transport	Terms of Reference	22.04.2013
Driver/origin:	Safety	Rulemaking group:	No
Reference:		RIA type:	Full
		Technical consultation during NPA drafting:	N/A
		Publication date of the NPA:	N/A
		Duration of NPA consultation:	N/A
		Review group:	No
		Focussed consultation:	No
		Publication date of the Decision:	N/A

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1. Procedural information

1.1. The rule development procedure

The European Aviation Safety Agency (hereinafter referred to as the 'Agency') developed ED Decision 2014/024/R in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2].

This rulemaking activity is included in the Agency's Rulemaking Programme for 2014-2017 under RMT.0075 (26.008)[3]. The scope and timescale of the task were defined in the related Terms of Reference (see process map on the title page).

The Agency developed a Regulatory Impact Assessment (RIA) comparing the default option of 'no regulatory change', to the option for a mandatory retrofit[4] of Flammability Reduction Means on certain already Type-Certificated Large Aeroplanes. The RIA, concludes that no rulemaking action is required due to the large imbalance between the limited safety benefit and the associated large costs. Therefore, this Decision provides no amendment to existing rules nor additional rules, and terminates the rulemaking action related to this subject.

1.2. Structure of the related documents

This Decision provides no amendment to existing rules nor additional rules, in accordance with the results of the RIA.

The Regulatory Impact Assessment is annexed to this explanatory note.

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1 Regulation (EC) No 216/2008 of the European Parliament and the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1), as last amended by Commission Regulation (EU) No 6/2013 of 8 January 2013 (OJ L 4, 9.1.2013, p. 34).

2 The Agency is bound to follow a structured rulemaking process as required by Article 52(1) of the Basic Regulation. Such process has been adopted by the Agency's Management Board and is referred to as the 'Rulemaking Procedure'. See Management Board Decision concerning the procedure to be applied by the Agency for the issuing of opinions, certification specifications and guidance material (Rulemaking Procedure), EASA MB Decision No 01-2012 of 13 March 2012.

3 See: http://easa.europa.eu/document-library/terms-of-reference/tor-26008-issue-1.

4 A 'production cut-in' is effective based on SIB 2010-10: Fuel Tank Safety – Flammability Reduction System (FRS) for High Flammability Exposure Fuel Tanks – Production Cut-in

2. Explanatory Note

2.1. Overview of the issues to be addressed

Several aeroplane fuel tank explosion events occurred during the last twenty-five years.

The investigations led to changes in the EASA certification requirements for new designs (CS-25), addressing ignition prevention and fuel tank flammability exposure.

The Federal Aviation Administration (FAA) amended similarly FAR-25 but also implemented operational rule changes that require the retrofit of Flammability Reduction Means (FRM) or Ignition Mitigation Means (IMM) on certain in-service aeroplane types.

This is the major difference between the current EASA and FAA regulations on this subject.

For a more detailed analysis of the issues addressed by this proposal, please refer to the section 1 'Issues to be addressed', of the RIA in Annex.

2.2. Objectives

The specific objective of rulemaking task RMT.0075 (26.008) was to consider improvement of the protection of occupants on board large aeroplanes operated in commercial air transport (CAT), by reducing the risk of fuel tank explosion.

2.3. Outcome of the consultation

No Notice of Proposed Amendement (NPA) was provided for public consultation to the interested parties.

Three Regulatory Impact Assessments (RIAs) have been produced on the issue: in 2004, 2008 and 2013, and shared with the Advisory Bodies.

Following the last issue of the RIA, the Agency decided that this rulemaking task does not require further rulemaking action and can, therefore, be closed.

2.4. Summary of the Regulatory Impact Assessment (RIA)

The RIA compared the option for a mandatory retrofit to the default option of 'no regulatory change'. The 'no regulatory change' option would create no additional rules. Since CS-25 was amended several years ago and the production cut-in is effective, the progressive phase-out of 'old' aeroplanes would gradually remove the risk from the fleet.

A mandatory retrofit of the whole affected fleet as per Option 1 would reduce the safety risk and statistically prevent 0.22 accidents and 37 fatalities over the 2013-2036 period. The rule costs are estimated to amount to EUR 662 million[5] in total and EUR 17,9 million per fatality prevented. This is not considered to be cost-effective.

Therefore, the RIA concludes that no rulemaking action is required due to the large imbalance between the limited safety benefit and the associated large costs.

2.5. Overview of the amendments

Neither amendment to existing rules nor additional rules are provided by this Decision, in accordance with the results of the RIA.

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[5] 2013 EUR, costs discounted at 4 %.

3. References

3.1. Related regulations

None.

3.2. Affected decisions

None.

3.3. Reference documents

- FAA SFAR 88: Fuel Tank System Fault Tolerance Evaluation Requirements
- FAR 25.981: Fuel tank ignition prevention
- FAR 26.35: Changes to type certificates affecting fuel tank flammability
- FAR 26.33: Fuel Tank Flammability
- CS 25.981: Fuel tank ignition prevention
- EASA Safety Information Bulletin (SIB) 2010-10 Fuel Tank Safety — Flammability Reduction System (FRS) for High Flammability Exposure Fuel Tanks — Production Cut-in
- RIA for the introduction of a Flammability Reduction System (2004, 2008, and 2013 issue)
- NPA 2008-19: Fuel Tank Flammability Reduction
- NPA 2012-13: Additional airworthiness requirements for operations
- Opinion No 08/2013 : Additional airworthiness requirements for operations

4. Appendix

Regulatory Impact Assessment RMT.0075 (26.008).

1. Regulatory Impact Assessment (RIA)

1.1. Issues to be addressed

(a) Definition and history of the issue: Fuel tank flammability reduction of large aeroplanes

On 17 July 1996, a Boeing 747-100 aeroplane exploded in flight near Long Island, USA (TWA800 accident)[6]. Other similar events occurred during the last twenty-five years. The identified cause was an explosion of the fuel tank, but the exact ignition source was not identified.

In the past years, the FAA and the Joint Aviation Authorities (JAA) took various measures (SFAR 88 and corresponding JAA policy 04/00/02/07/03-L024) to reduce the risk of fuel tank ignition on in-service aeroplanes. They required evaluation of the fuel tanks and, if needed, incorporation of design features to keep ignition sources outside of the fuel tank.

Concerning the certification of new large aeroplane types, the Agency (replacing the JAA) introduced in CS-25 Amendments 1, 6 and 9 new specifications addressing ignition prevention and fuel tank flammability exposure, as well as the eventual introduction of Flammability Reduction Means (FRM) to mitigate high flammability exposure (refer to NPA 2008-19[7] and CRD 2008-19[8] for further details). This led to the introduction in CS-25 of a new subparagraph CS 25.981(b) and the new Appendices M and N. With these amendments, the Agency considers the identified risks to be appropriately mitigated for **new designs**.

A Regulatory Impact Assessment (RIA) was performed in 2004 in order to evaluate the costs and benefits of installing FRM on already certified large aeroplanes featuring high flammability exposure fuel tanks.

In 2008, a revised RIA was issued by an EASA working group, considering the revised cost data available from FRM equipment suppliers, as well as aeroplane manufacturers. The result of the independent study (by R.W.G. Cherry and Associates), which aimed at assessing the need for retrofit, was reviewed by the group.

Both RIAs concluded that a requirement for **new deliveries** of existing types (‘production cut-in’) was justified, whereas a retrofit of the **existing fleet** was not considered justified. Following this ‘2008’ RIA, the Agency issued in March 2010 Safety Information Bulletin (SIB) 2010-10 recommending that, from 1 January 2012, all new production airframes identified as having a fuel tank with high flammability exposure should be fitted with a FRM. This production cut-in was accepted by the manufacturers.

However, the conclusion of the RIA was not in line with the FAA actions and regulations in terms of flammability reduction means on aeroplanes that were already certified and in-service.

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6 National Transportation Safety Board Aircraft Accident Report: http://www.ntsb.gov/doclib/reports/2000/AAR0003.pdf

7 http://easa.europa.eu/rulemaking/docs/npa/2008/NPA%202008-19.pdf

8 http://easa.europa.eu/rulemaking/docs/crd/2008/CRD%202008-19.pdf

In addition to an amendment to FAR-25, the FAA also issued FAR 26.33 and FAR 26.35 for the in-service fleet, which required a flammability exposure analysis on large aeroplane fuel tanks and auxiliary body fuel tanks. The result of this analysis led the FAA to implement operational rule changes that require the retrofit of FRM on in-service aeroplane types that were found as having a high flammability exposure. This is the major difference between the current EASA and FAA regulations.

The Agency has acknowledged the lack of harmonisation between the US and the EU and is also concerned by the remaining safety risk for the European fleet in the absence of full retrofit requirements. It had, therefore, started a rulemaking task to address the remaining risk.

In 2012, the subject has been presented to the Rulemaking Advisory Group (RAG) and Thematic Advisory Group (TAG), which both asked for updated data. This data is provided through this new Regulatory Impact Assessment.

(b) Regulatory framework for mandating design changes to the existing fleet: additional airworthiness specifications for operations and safety improvement

In the JAA system, retroactive requirements were covered under JAR-26 (Additional Airworthiness Requirements for Operations); Subpart B was dedicated to Commercial Air Transport (Aeroplanes). If rendered mandatory by Member States' national legislation, they were/are applicable to operators of large aeroplanes. Further subparts in JAR-26 were reserved for other categories of aeroplanes and operations, but were not used.

In the framework of the Agency's rulemaking task 21.039[9], the Agency intended to define a new regulatory framework for the elaboration and adoption of additional airworthiness specifications for a given type of aeroplane and type of operation. An initial proposal was made through NPA 2009-01, and the corresponding CRD 2009-01 was published on 13 May 2011. As a result of the comments received, the Agency has decided that the most adequate method to introduce additional airworthiness requirements on already certified products will be through dedicated Implementing Rules (IRs) supported by Certification Specifications. This means that a new Regulation with an Annex called 'Part-26' will be created. The high-level requirement, applicability and entry into force will be covered by Part-26. The technical details on how to comply with this high-level requirement will be contained in the new Certification Specifications 'CS-26'.

RMT.0110 (previously 21.039(k)) covers the transfer of existing JAR-26 Amendment 3 requirements into the new Part-26 and CS-26. The Agency issued NPA 2012-13[10], proposing the new Implementing Rule and associated CS. The associated CRD 2012-13[11] has been published on the EASA website, followed by Opinion No 08/2013 which was published on 25 September 2013.

In addition, the Agency is also developing additional airworthiness specifications for operations which are identified in the Agency's Rulemaking Programme. RMT.0075 is

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9 Rulemaking task 21.039 contains additional subtasks from 21.039(a) to 21.039(k) in support of the Operational Suitability Data concept. Please refer to the Rulemaking Programme for details.

10 http://easa.europa.eu/rulemaking/docs/npa/2012/NPA%202012-13.pdf.

11 http://easa.europa.eu/rulemaking/docs/crd/2012/CRD%202012-13.pdf.

one of these tasks and proposes requirements that were not previously contained in JAR-26.

1.1.1 Safety risk assessment

In the past 25 years, four civil aeroplane fuel tank explosions have occurred worldwide. Three of them occurred on ground, and one in flight.

The reported accidents have resulted in 239 fatalities and 30 injuries.

Table 1: Fuel tank explosion worldwide

Date	Aeroplane	Flight Phase	Fatalities	Injuries	Escaped
11 May 1990	B737-300	Push-back	8	30	82
17 July 1996	B747-100	Climb	230	-	-
3 March 2001	B737-400	Parked	1	-	7
4 May 2006	B727-200	Parked	-	-	4

The FAA quoted in its economic evaluation an engineering analysis by Boeing stating that if an aeroplane fuel tank explosion occurs, the probability that it happens in flight is 80 %[12].

An in-flight aeroplane fuel tank explosion would normally result in a high number of fatalities. It is expected to have a smaller number of fatalities if such explosion occurs on the ground.

In any case, the consequence is considered as catastrophic.

1.1.2 Who is affected?

Organisations:

— Aeroplane Type Certificate Holders;

— Operators;

— Maintenance Organisations;

— Leasing companies; and

— Fuel Tank STC holders.

Aeroplanes:

The following in-service aeroplanes have been shown to have fuel tanks which have a high flammability exposure for their centre wing tanks:

— Boeing 707, 737, 747, 757, 767, 777,

— Airbus A300/A310, A320 family, A330/A340.

In addition, the auxiliary tanks on Boeing (ex-McDonnell Douglas) DC-10 and DC-9/MD-80, and Supplemental Type Certificates (STCs) introducing unpressurised auxiliary tanks in the cargo compartment were considered having a high flammability exposure.

Since 2004, the production of the B757, A300/A310 and A340 has ceased. Most unpressurised auxiliary fuel tanks have been deactivated by the issuance of Airworthiness Directives (ADs). Generally, the dramatic increase of the fuel price has speeded up the fleet replacement process by replacing older aeroplanes by more fuel-efficient aeroplanes.

[12] http://www.gpo.gov/fdsys/pkg/FR-2008-07-21/pdf/E8-16084.pdf

The production cut-in, which was proposed in SIB 2010-10, had been accepted by both manufacturers. This resulted in FRM being part of the basic configuration of all affected aeroplanes making their first flight after 31 December 2011.

Table 2: Affected types by size[13]

Make	Single aisle	Wide-body
Airbus	A320 family	A330/340
Boeing	737	747, 757, 767, 777

1.1.3 How could the issue/problem evolve?

In order to evaluate the probability of future accidents based on the data available, one would need to take into consideration that the risk of an aeroplane fuel tank explosion is proportionate to the number of flight hours performed by the affected aeroplanes.

The number of accidents also depends on the effectiveness of efforts that are already in place to reduce the risk of ignition in the fuel tank (SFAR 88 and JAA policy[14]).

In the 2003–2012 period, the average annual flight hours for European operators were as follows:

Table 3: Average annual flight hours

	SA	WB	Total
Airbus	2 795	4 737	3 166
Boeing	2 826	3 910	3 255
Total	2 810	4 151	3 214

Table 4: Number of affected fleet (2013)

	SA	WB	Total
Airbus	1 191	208	1 399
Boeing	475	230	705
Total	1 666	438	2 104

Based on the current situation (production cut-in effective and new designs covered), on a 25-year average service life, and on the average annual flight hours mentioned above, it is estimated that the affected types are going to fly 112 million hours before their retirement (see Attachment ,Table 15 and Table 17).

The basic ignition rate retained for our analysis, like in 2004 and 2008, is 1×10^{-8} per Flight Hour (FH).

The ignition rate and the number of accidents expected in a 'no change' situation (Option 0) evolve with the assumed level of effectiveness of the ignition prevention efforts (SFAR 88), as per the table below:

[13] The other aeroplanes previously identified would fall out of the average service life. (They are estimated to permanently retire before the changes are mandated.)

[14] CS-25 has been amended to incorporate the provisions of the JAA policy.

Table 5: Accidents (ignition rate) per 100 million flight hours

Ignition (number of accidents)	per 100 million FH (flight hours)	2013–2036 (112 million FH)
Basic (without SFAR)	1.00	1.12
SFAR 25% efficiency	0.75	0.84
SFAR 50% efficiency	**0.50**	**0.56**
SFAR 75% efficiency	0.25	0.28

This leads to the conclusion that, in a non-regulatory change scenario, it is expected that from 0.28 to 0.84 aeroplane fuel tank explosions will occur in Europe in the period 2013–2036. In other words, there is a 28 to 84 % probability that a fuel tank explosion will take place in the next 23 years, depending on the effectiveness of the SFAR 88 measures.

Based on the above analysis (for the annual number of projected accidents by make and size assuming 50 % SFAR 88 effectiveness, see Attachment, **Table 20**), the likelihood of an aeroplane fuel tank explosion is considered improbable. The severity of the occurrence can be catastrophic. Therefore, the combined aeroplane fuel tank explosion risk is considered to be of high significance. The following section will define the objectives based on this safety issue, and section 4.3 will identify the options of how to address the issue.

1.2. Objectives

The overall objectives of the Agency are defined in Article 2 of the Basic Regulation. This proposal will contribute to the overall objectives by addressing the issues outlined in Section 4.1.

The specific objectives of this proposal are, therefore, twofold:

— to reduce the risk of an aeroplane fuel tank explosion; and

— to achieve harmonisation, as far as possible, with the FAA regulations.

1.3. Policy options

Table 6: Selected policy options

Option No	*Short title*	**Description**
0	**'No regulatory change'**	Baseline option (no change in rules; risks evolve as estimated in the issue analysis)
1	**Retrofit**	Mandate the production cut-in and retrofit of the affected in-service aeroplanes in a given timeframe: we could envisage a 10-year period to have 100 % of the fleet retrofitted (2014-2023), with a deadline for operators to have 50 % of their fleet retrofitted by the end of 2020.

1.4. Methodology and data

1.4.1 Applied methodology

The benefits and costs of the options identified in the previous sections mainly depend on the unit costs of the FRM as well as the speed at which these systems will be introduced into the fleet.

In real life, the number of accidents and fatalities can only be a whole number and not a fraction (either an accident occurs or it doesn't). However, using whole numbers for infrequent events could lead to significantly misleading results. For this reason, it is appropriate to use fractions for greater accuracy.[15]

1.4.2 Multi-criteria analysis

The term multi-criteria analysis (MCA) covers a wide range of techniques that share the aim of combining a range of positive and negative impacts into a single framework to allow easier comparison of scenarios. Essentially, it applies cost/benefit thinking to cases where there is a need to present impacts that are a mixture of qualitative, quantitative and monetary data, and where there are varying degrees of certainty.

Key steps of an MCA generally include:

(a) Establishing criteria to be used to compare the options (these criteria must be measurable, at least in qualitative terms);

(b) Assigning weights to each criterion to reflect its relative importance in the decision;

(c) Scoring how well each option meets the criteria; the scoring needs to be relative to the baseline scenario;

(d) Ranking the options by combining their respective weights and scores; and

(e) Performing sensitivity analysis on the scoring so as to test the robustness of the ranking.

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[15] In most tables of this analysis, results are shown as rounded to one or two decimals, but the calculation of the totals is made without rounding, therefore, the total numbers might differ slightly from the sum of the individual rounded values.

The objectives for this rulemaking activity have been outlined in Section 4.2. The options have been described above and will be analysed in the following section for each of the assessment areas. The criteria used to compare the options were derived from the Basic Regulation and the guidelines for Regulatory Impact Assessment developed by the European Commission[16]. The principal objective of the Agency is to 'establish and maintain a high uniform level of safety' (Article 2 (1)). As additional objectives, the Basic Regulation identifies environmental, economic, proportionality and harmonisation aspects, which are reflected below.

Table 7 shows the weights that were assigned to the individual groups of criteria. Based on the above considerations and the mandate of the Agency, safety received the highest weight of 3. Environmental impacts are attributed with a weight of 2 as the Agency has certain specific responsibilities in this area related to noise and emissions. For the same reason, impacts on the other assessment areas are attributed with a weight of 1 since these areas are to be duly considered when developing the implementing rules. Each option developed below will be assessed based on the above criteria. Scores are used to show the degree to which each of the options achieves the assessment criteria. The scoring is performed on a scale between -5 and +5.

Table 7: Assessment criteria for the multi-criteria analysis

Overall Objectives	**Specific Objectives and assessment criteria**	
	Weight	**Description**
Safety	3	Maintain or improve the level of safety
Economic	1	Ensure cost-effective aviation safety rules Ensure 'level playing field'
Environment	2	Avoid negative effects on the environment
Social	1	Avoid negative effects on social issues Promote high-quality jobs in the private sector for aviation
Equality and proportionality	1	Ensure proportionate rules for Small and Medium sized Enterprises (SMEs)/General aviation/Business Aviation
Regulatory harmonisation	1	Ensure full consistency with EU laws and regulations Ensure compliance with ICAO standards (if appropriate) Achieve the maximum appropriate degree of harmonisation with the FAA/TCCA equivalent rules for commercial aviation

[16] http://ec.europa.eu/smart-regulation/impact/key_docs/key_docs_en.htm

Table 8 gives an overview of the scores and their interpretation.

Table 8: Scores for the multi-criteria analysis

Score	Descriptions	Example for scoring options
+5	Highly positive impact	Highly positive safety, social or environmental protection impact. Savings of more than 5 % of annual turnover for any single firm; Total annual savings of more than EUR 100 million
+3	Medium positive impact	Medium positive social, safety or environmental protection impact. Savings of 1 % - 5 % of annual turnover for any single firm; Total annual savings of EUR 10-100 million
+1	Low positive impact	Low positive safety, social or environmental protection impact. Savings of less than 1 % of annual turnover for any single firm; Total annual savings of less than EUR 10 million
0	No impact	
-1	Low negative impact	Low negative safety, social or environmental protection impact. Costs of less than 1 % of annual turnover for any single firm; Total annual costs of less than EUR 10 million
-3	Medium negative impact	Medium negative safety, social or environmental protection impact. Costs of 1 % - 5 % of annual turnover for any single firm; Total annual costs of EUR 10-100 million
-5	Highly negative impact	Highly negative safety, social or environmental protection impact. Costs of more than 5 % of annual turnover for any single firm; Total annual costs of more than EUR 100 million

1.4.3 Cost-effectiveness analysis

Complementing the MCA, in the analysis of impacts, we used cost-effectiveness analysis to calculate the cost associated to preventing one fatality[17]. Cost-effectiveness analysis ranks regulatory options based on 'cost per unit of effectiveness', i.e. cost per fatalities avoided.

In order to avoid a result that concentrates only on a single type of benefit (i.e. the number of fatalities avoided), the net cost was calculated, which takes into account the benefit of avoided aeroplane damage and accident investigation costs.

To make results comparable, all monetary values are expressed in 2013 euros. For future costs and benefits, a standard discount rate of 4 %[18] was applied and past costs were inflated with the same value. Discounted euro values are marked with the PV (Present Value) abbreviation in columns right from the undiscounted figures.

The benefits are accrued during the period while the aeroplanes with updated wing tank are in service (2021–2036), and the costs of installation are incurred in 2021 and 2024, the years by which 50 % and 100 % of the fleet has to be retrofitted. Operating costs are parallel with the benefits (2021–2036).

[17] See p. 46 of the European Commission Impact Assessment Guidelines (SEC(2009) 92).

[18] The numbers of accidents, fatalities and injuries prevented are not discounted. While economic theory suggests a time preference also for non-monetary benefits, discounting the number of fatalities prevented does not change the relative cost-effectiveness of the options compared to each other. The final recommendation of the RIA is not sensitive to discounting.

1.4.4 Data collection

The unit costs estimated in this RIA are based on information of the 2004 and 2008 EASA Regulatory Impact Assessments and have been updated and validated by data provided by aeroplane manufacturers and operators. The fleet evolution and average annual flight hours are based on data from ASCEND[19].

In the analysis of impacts, the various affected models are grouped into four categories by make (Airbus and Boeing) and size (single aisle (SA) and wide-body (WB)).

1.5. Analysis of impacts

The scope of the proposed measures in terms of number of affected aeroplanes is defined as follows:

— Taking into account the time to issue the regulation, a reasonable time frame to retrofit, and the average service life of an aeroplane (25 years), we can assume that aeroplanes which were in service before 1998 can be excluded from the affected population.

— Similarly to the FAA, cargo aeroplanes would be excluded from the scope[20].

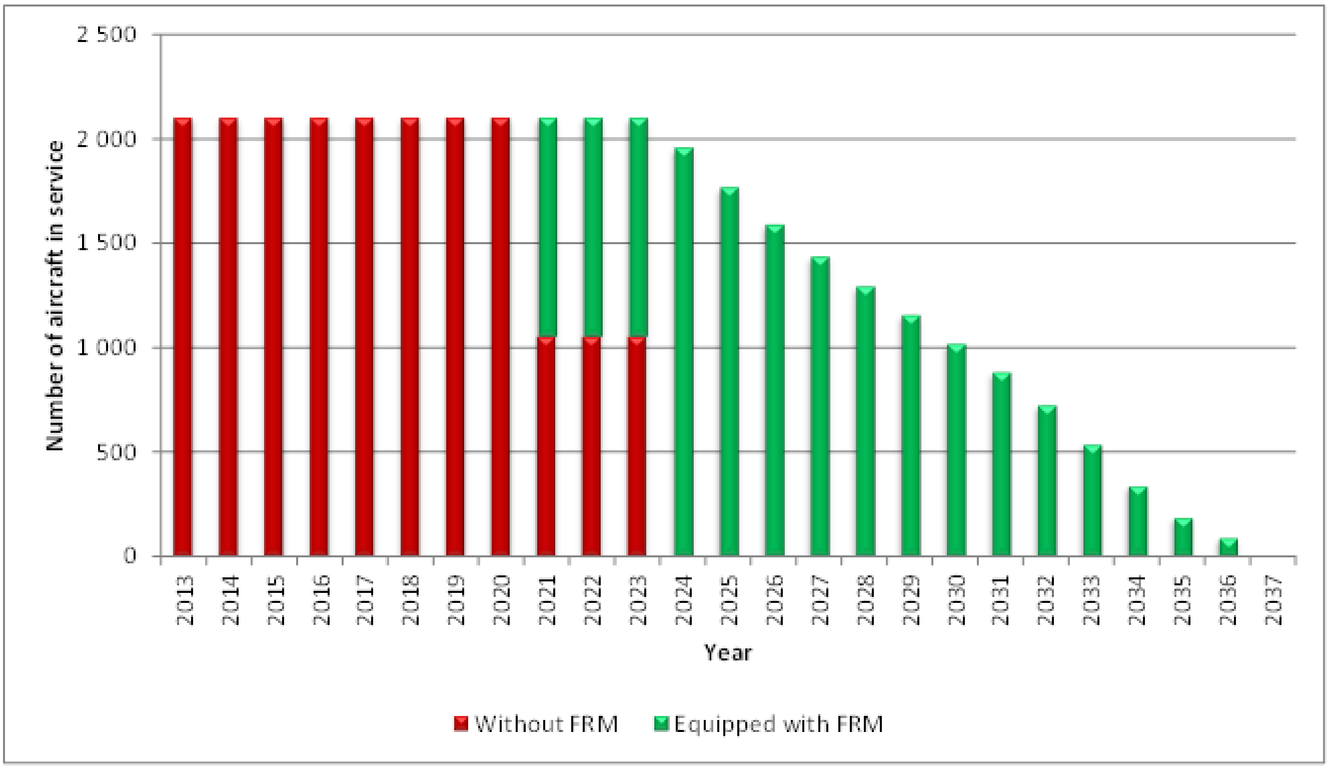
— For some models, the production stopped before 2011, for others FRM were already introduced in production before the cut-in date.

Combining all this data allows to obtain an estimation of the evolution of the EU-operated fleet with high flammability exposure. The following graph shows how this fleet is expected to retire from around 2 100 aeroplanes in 2013 to zero by the end of 2036.

[19] Ascend is a part of Flightglobal, providing global aviation industry data. (www.ascendworldwide.com)

[20] The total number of flight hours performed by the affected cargo aeroplanes is significantly low compared to the passenger carrier aeroplanes.

Figure 1: Number of affected aeroplanes[21] with Option 1



The options identified result in different speeds at which the FRM is introduced in the fleet.

Option 0 is the reference option as described in the issue analysis in section 1. Since the production cut-in started in 2012, and taking into account an average service life of 25 years, it can be assumed that by 2036 all the affected aeroplanes without FRM will retire. Therefore, the entire remaining fleet will be equipped with FRM by design.

Option 1 mandates FRM installation on all new deliveries and on all in-service aeroplanes, i.e. all the affected fleet would need to be equipped with FRM by 2023. With this option, 50 % of the fleet would need to be equipped by 2021.

1.5.1 Safety impact

In the analysis of the safety impact, the risk of an accident during the lifetime of the affected fleet is estimated in a no-change scenario (Option 0). This option is compared to Option 1 by establishing the number of accidents that could be prevented thanks to FRM. The potential safety benefit of installing FRM is then the number of accidents avoided. The impacts of these accidents are analysed in terms of fatalities prevented, aeroplane damages and accident investigation costs prevented.

The safety impact depends on the speed at which the FRM is introduced into the fleet and is proportionate to the number of flight hours performed.

As described in section 1.1.3, the 2 104 aeroplanes that are in the fleet of European operators are estimated to fly 112 million flight hours in their remaining service life, i.e. until the end of 2036, when the last aeroplanes without FRM are expected to retire.

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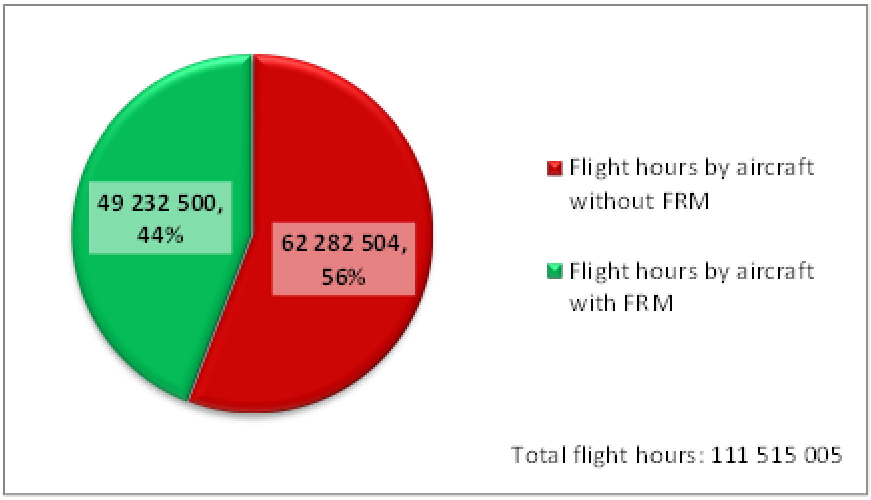
[21] In service and storage.

If 50 % of the affected fleet is equipped with FRM by the end of 2020 and the whole fleet by the end of 2023, then the 2 104 aeroplane fleet is going to fly 62 million hours without FRM and 49 million hours equipped with FRM before leaving service in 2036 (see **Figure 2: Estimated flight hours with and without** FRM, and for more details Attachment, **Table 18: Flight hours of high flammability types without** FRM, and Attachment, **Table 19: Flight hours of high flammability types equipped with** FRM).

Figure 2: Estimated flight hours with and without FRM



In our analysis, similarly to the FAA, it is assumed that the SFAR 88 efforts have a 50 % effectiveness, and the proposed FRM has a 90 % effectiveness. Table 9 summarises the number of estimated accidents without FRM (Option 0), and the number of accidents that could be avoided by FRM. The number of accidents with Option 1 and the number of accidents avoided is proportionate to the share of flight hours without and with FRM (respectively 62 and 49 million hours).

The number of accidents is expected to decrease from 0.56 to 0.34. This decrease of 0.22 represents a 39% fall in the probability of an accident.

The benefits of avoiding 0.22 explosions include 37 fatalities prevented[22], EUR 1.1 million aeroplane damage avoided and EUR 0.7 million accident investigation costs saved.

Attachment Table 20 Projected number of aeroplane accidents with Option 0, and Attachment Table 23: Projected number of accidents avoided by FRM show the estimated annual number of accidents by manufacturers and aeroplane categories.

Table 9: Estimated number of accidents and fatalities (2013–2036)

Description	Accidents			Fatalities
	Option 0	Option 1	Avoided	prevented
Basic ignition rate (without SFAR)	1.12	0.67	0.44	74
SFAR 25% efficiency	0.84	0.50	0.33	55
SFAR 50% efficiency	**0.56**	**0.34**	**0.22**	**37**
SFAR 75% efficiency	0.28	0.17	0.11	18

22 0.22 avoided accident means that there is a 22 % chance that 167 fatalities can be avoided, which is represented as 0.22 × 167 = 37 fatalities prevented.

The most important assumptions for the calculation of the safety benefits of Option 1 were the following:

— Number of affected aeroplanes in service and temporary storage in 2013: 2 104
— Total flight hours (2013–2036): 112 million, thereof
  - Flight hours by aeroplanes without FRM (2013–2023)[23]: 62 million
  - Flight hours by aeroplanes with FRM (2021–2036): 49 million
— SFAR 88 effectiveness rate: 50 %
— FRM effectiveness rate: 90 %
— Percentage of in-flight accidents: 80 %
— Percentage of on-the-ground accidents: 20 %
— Average seat capacity: 255
— Average occupancy rate: 80 %
— Average number of passengers: 204
— Average fatalities per accident: 167

Based on the above data, Option 1 is estimated to have a low positive safety impact (MCA score +1).

1.5.2 Environmental impact

In this analysis we estimated the increased fuel consumption and CO_2 emission due to FRM. The approach is based on a method that is recommended by the European Commission-financed Harmonised European Approach for Transport Costing (HEATCO) research project. One of the main objectives of HEATCO is to create a consistent framework for monetary valuation and contribute to consistency with transport costing.

The costs are calculated first by estimating the increase in fuel burn, and then by multiplying the amount of CO_2 emission by a cost factor (see Table 10).

Table 10: Shadow price per tonne of CO_2 equivalent emitted (EUR)[24]

Year of emission	Central guidance	For sensitivity analysis	
		Lower central estimate	Upper central estimate
2010–2019	26	14	51
2020–2029	32	16	63
2030−2039	40	20	81

For the amount of extra fuel burn caused by FRM, see 1.5.3.2 ***Ownership costs (maintenance and fuel)***. It is assumed that burning 1 kg of fuel creates 3.16 kg of CO_2

[23] 2021–2023 50 % of the fleet is equipped with FRM.

[24] In high altitudes, other emissions from aircraft than CO_2 (water vapour, sulphate and soot aerosols, as well as nitrogen oxides) have a considerable climatic effect. To take into account the warming effect of other emissions than CO_2, high altitude CO_2 emissions were multiplied by a factor of 2, as recommended by the HEATCO report based on recent research results.

emission (see Attachment, **Table 33**). The discounted monetary value of the emissions caused by the additional fuel burnt is EUR 11 million, which is 1.7 % of the total costs of Option 1. For the annual values of the shadow prices of the extra high altitude emissions, see Attachment, **Table 34** and **Table 35**.

The additional fuel consumption and CO_2 emission due to FRM are considered to have a low negative impact on environment (MCA score -1).

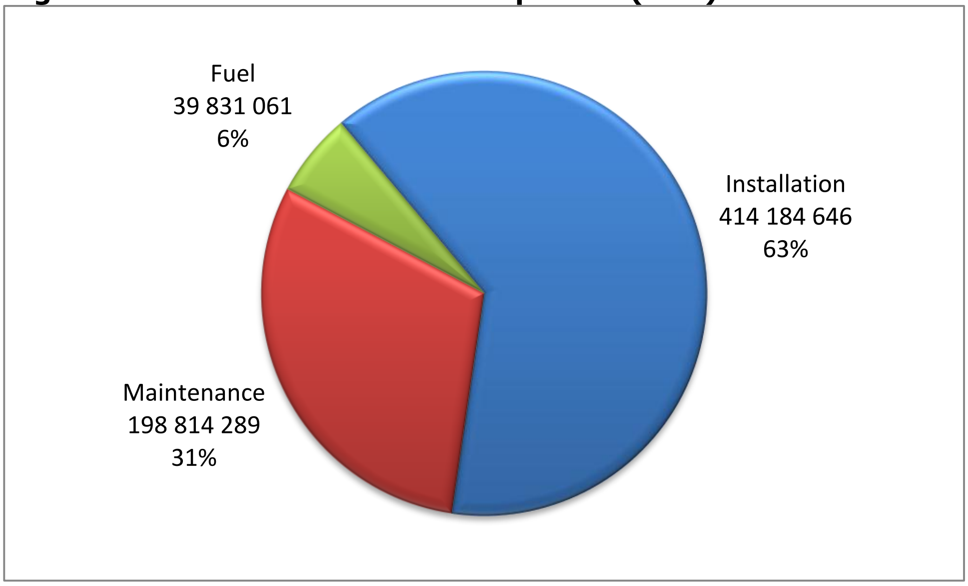
1.5.2.1 Additional Noise

Noise issues are very sensitive at European airports, but the FRM overall effect should be negligible in that respect.

1.5.3 Economic impact

The estimated present value of the cost of Option 1 is about EUR 652 million, which is detailed in the sections below (see also annual costs in Attachment, **Table 31** and **Table 32**). The costs can be grouped into installation costs (EUR 414 million) and ownership costs (EUR 239 million). The overall economic impact is considered a medium negative (MCA score -3) because of the considerable one-off installation costs and the presence of additional operational costs.

Figure 3: Breakdown of costs of Option 1 (EUR)



1.5.3.1 Installation costs

The unit cost of introduction of FRM is estimated to range from EUR 0.2 million to EUR 0.5 million in single-aisle and wide-body aeroplanes respectively. This value includes the kit pricing, the special tooling, the labour costs, and the additional aeroplane downtime necessary to install the system.

As far as labour costs are concerned, the assumed installation times range from 675 to 825 hours, based on information from the earlier 2004 and 2008 EASA Regulatory Impact Assessments and updates from manufacturers and maintenance organisations.

For the labour unit cost, an average hourly engineer rate of EUR 85 was assumed, which results in EUR 57–70 thousand labour cost per airframe.

It is assumed that the 10-year time period available for the installation of the system allows it to be done during scheduled maintenance, therefore, the additional specific aeroplane downtime is going to be limited to one day, which costs EUR 10 thousand for single aisle and EUR 30 thousand for wide-body aeroplanes.

For the entire European affected fleet, the cost of retrofitting is expected to be EUR 414 million.

1.5.3.2 Ownership costs (maintenance and fuel)

The value includes the operating costs of annual maintenance, materials, and the cost of additional fuel burnt. Although the shadow price of the additional gaseous emissions is evaluated separately in section 1.5.2. Environmental impact, it is taken into account in the final evaluation expressed in monetary values.

Taking into account the estimated weight of the FRM on single aisle and wide-body aeroplanes, it is envisioned that the additional fuel consumption ranges from 0.6 gal/FH[25] (Single Aisle) to 2 gal/FH (Wide Body). The global additional fuel consumption is approximately 28 million gallons, which amounts to EUR 40 million, as detailed in Attachment Table 26. The cost of additional fuel was calculated with a EUR 2.33 per gallon price.

Maintenance costs include the annual maintenance cost and the cost of the air separation module replacements, which is assumed to have an average 27 000-hour lifetime. The annual maintenance costs are EUR 199 million (see Attachment, Table 29 and Table 30).

After maintenance involving fuel tank entry, it is likely that some increase in APU or engine running time may be necessary to ensure that the Flammability Reduction Means (FRM) is fully recharged before operating the aeroplane. This would imply marginal increase in fuel consumption, which was not taken into account in this analysis. Over the analysis period, the total ownership costs are estimated to be EUR 239 million.

1.5.3.3 Aeroplane damages avoided

The estimated values of 15–20 year-old single-aisle and wide-body aeroplanes are EUR 6 and EUR 13 million respectively, based on data from Ascend. An aeroplane with a fuel tank explosion is considered totally destroyed, regardless of whether it is an in-flight or on-the-ground event.

The average damage was calculated by weighting the single-aisle and wide-body replacement values with the number of aeroplanes and the average annual flight hours, resulting in EUR 8.2 million. Because the estimated number of accidents avoided is less than one, the saving is also calculated to be less than EUR 8.2 million. The discounted value of preventing the destruction of 0.22 aeroplane is EUR 1.1 million. For the undiscounted values and the average annual savings see Attachment, Table 21 and Table 22).

1.5.3.4 Accident investigation costs saved

The 2008 FAA regulatory evaluation estimated the accident investigation costs of an on-the-ground and an in-flight explosion to be USD 1 and 8 million respectively. It also acknowledges that the accident investigation costs of an in-flight explosion over hard-to-

[25] FH: flight hour

reach terrain might be significantly higher. The costs may also be even higher because an in-flight explosion might initially be indistinguishable from a terrorist attack.

In this analysis, we used a EUR 5-million value for the cost of an average accident investigation. This is based on the US values converted to euro[26] and weighted by the probabilities of an in-flight and on-the-ground explosion. The discounted value of the accident investigation costs saved by avoiding 0.22 accidents is EUR 0.7 million. For annual details by make and size categories, see Attachment, Table 24 and Table 25.

1.5.4 General aviation and proportionality

Although the proposed Option 1 does not affect General Aviation, its economic impacts might be heavier on operators who have a large share of the affected types in their fleet. This impact, however, is limited by the length of the transitionary period. The expected impact on proportionality, therefore, is low negative (MCA score -1).

1.5.5 Impact on 'Better Regulation' and harmonisation

In addition to an amendment to FAR-25, the FAA also issued FAR 26.33 and FAR 26.35 which required a flammability exposure analysis on large aeroplane fuel tanks and auxiliary body fuel tanks. The result of this analysis led the FAA to implement operational rule changes which require the retrofit of an FRM on in-service aeroplane types which were found as having a high flammability exposure.

The FAA required that 100 % of the affected fleet is retrofitted by 2017.

Imposing the retrofit (although in a different time frame) would help harmonise with the FAA regulation.

Other major foreign authorities such as Brazil have similarly issued a retrofit rule for FRM. For these reasons, Option 1 has a low positive impact on regulatory harmonisation.

1.6. Comparison and conclusion

1.6.1 Comparison of options

Option 0 represents a fleet of 2 104 aeroplanes with a high flammability risk which are expected to retire gradually by the end of 2036. They are estimated to fly 112 million hours, with an estimated risk of 0.56. In other words, there is a 56 % probability that an explosion would happen between 2013 and 2036, based on the number of aeroplanes in service and their projected future flight hours.

Option 1 would require the retrofit of FRM to the whole fleet by the end of 2023. This is estimated to avoid 0.22 accidents of the 0.56 and statistically prevent 37 fatalities.

The identified options can be compared using the multi-criteria analysis (MCA) and the cost-effectiveness indicator. An overview of the results can be found in Table 11 on page 23.

As far as cost-effectiveness is concerned, the statistical net cost of EUR 17.9 million per fatality prevented is significant. This compares to a standard figure of EUR 2 million per fatality[27], which is considered a standard value for cost-benefit analysis of this kind. Based on this indicator, **Option 1 is not considered cost-effective**.

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[26] The Agency used the 2012 European Central Bank annual average reference exchange rate of 1.2842.
[27] As recommended by the Impact Assessment Guidelines of the European Commission (15 January 2009, Annex p42).

MCA allows to consider the cost impacts at the same time as the non-monetised impacts and, thus, gives a broader picture:

— Other major certifying authorities have mandated the retrofit. Option 1 is considered to have a low positive impact on regulatory harmonisation.

— The economic impacts are expected to be heavier on smaller operators who have a large share of the relevant types in their fleet.

The sensitivity analysis below has shown that the overall cost-effectiveness **result is highly sensitive** to the assumption on how effective the SFAR 88 requirements are.

In conclusion, taking into account the results of the multi-criteria and sensitivity analysis, the Agency proposes no retrofit (Option 0) because the low probability of preventing an accident (22 %) in the period up to 2036 does not justify the high costs.

1.6.2 Sensitivity analysis

— One key assumption during the analysis is a SFAR 88 effectiveness of 50 %. One may suggest that the level of effectiveness is greater than in our analysis, therefore, the number of accident prevented by FRM would be lower than what is expected in this analysis.

— Table 9, on page, 17 shows that if SFAR is 75 % effective, then FRM is estimated to prevent 0.11 accidents and 18 fatalities.

— Consequently, the overall result of the analysis in terms of cost-effectiveness is highly sensitive to the assumption on the effectiveness of SFAR 88. An accident caused by a FRM failure or an installation error during a major retrofit cannot be entirely ruled out.

— Potential hazards to maintenance personnel associated with FRM must also be recognised. This can, however, be mitigated by the fuel tank entry safety procedures, equipment and training being already in place.

Table 11: Overview of impacts (Option 1: retrofit; EASA operators, 2012–2036)

Criteria (weight)	**Qualitative impacts**	**Quantitative measure**		**MCA score Unweighted**	**MCA score Weighted**
Safety (3×)	Flammibility Reduction Means (FRM) to mitigate high flammability exposure were introduced to new designs and new deliveries earlier, but the retrofit of FRM on in-service aircraft were not mandated.	Accidents avoided: Fatalities prevented: Reduction in accident costs (A):	0.22 37 EUR 1 731 107	1	3
Environment (2×)		Additional tonnes of fuel burn: Additional tonnes of CO2 emmission: Shadow price of CO2 emmission (B):	88 086 277 382 EUR 10 992 216	-1	-2
Economic		Costs of installation (C): Recurring costs (D):	EUR 414 184 646 EUR 238 645 350	-3	-3
Social	No change in working conditions.			0	0
Proportionality				-1	-1
Reguralory harmonisation	The US Federal Aviaiton Authority (FAA) has already mandated the retrofit of in-service aircraft.			1	1
Overall MCA score				-3	-2
Efficiency/ cost effectiveness		Total net costs ([B + C + D] - A): Net cost per fatality prevented:	EUR 662 091 106 EUR 17 895 213		

Notes: MCA scores are relative to Option 0, 'No regulatory change'. The table shows no more than two decimals but calculations were made without rounding.
All costs are in 2013 euros (discount rate: 4 %). Reduction in accident costs (A) includes aeroplane damages and accident investigation costs.
Recurring costs (D) are the costs of additional fuel burn and maintenance.

2. References

2.1. Affected regulations

Commission Regulation on Additional Airworthiness Requirements for Operations (still draft, see NPA 2012-13 and Opinion No 08/2013).

2.2. Affected CS, AMC and GM

Decision of the Executive Director of the European Aviation Safety Agency for Additional Airworthiness Specifications for Operations (CS-26) (still draft, see NPA 2012-13).

2.3. Referenced documents

— FAA SFAR 88: Fuel Tank System Fault Tolerance Evaluation Requirements

— FAR 25.981: Fuel tank ignition prevention

— FAR 26.35: Changes to type certificates affecting fuel tank flammability

— FAR 26.33: Fuel Tank Flammability

— CS 25.981: Fuel tank ignition prevention

— EASA Safety Information Bulletin (SIB) 2010-10 Fuel Tank Safety — Flammability Reduction System (FRS) for High Flammability Exposure Fuel Tanks — Production Cut-in

— RIA for the introduction of a Flammability Reduction System (2004 issue and 2008 issue)

— NPA 2008-19: Fuel Tank Flammability Reduction

— NPA 2012-13: Additional airworthiness requirements for operations

— Opinion No 08/2013 : Additional airworthiness requirements for operations

3. Attachment to the Regulatory Impact Assessment (RIA)

3.1. Fatalities prevented

The probability of an explosion is lower than 1. Although the number of accidents can only be a whole number in real life, fractions are used to better reflect the very low probability and frequency of the analysed event. Using whole numbers would lead to extremely misleading results. (0.22 accidents in a given time period means that there is a 22% probability that an accident happens).

The Agency estimated the average seat capacity of an aeroplane based on average typical number of seats of each affected model in each of the four aeroplane categories, weighted by the number of aeroplanes and the average flight hours of each category (see Table 12).

Table 12: Typical configurations and average number of seats[28]

Make	SA	WB
Airbus	117–199	274–332
Boeing	169–173	222–416

Make	SA	WB
Airbus	157	307
Boeing	173	323

The Agency assumed an 80 % average occupancy rate based on average load factor statistics from the Association of European Airlines (AEA) and the European Low Fares Airline Association (ELFAA). An in-flight explosion would cause 204 fatalities and an on-the-ground explosion would result in 20 fatalities. Finally, these figures were weighted by the probability of an in-flight and on-the-ground explosion (80 % and 20 % respectively), resulting in an average 167 fatalities per accident.

Attachment Table 20 shows the annual risk of an accident happening, represented mathematically by fractions. A 0.033 annual total number of accidents means that there is a 3.3 % probability of an accident happening in that year. The cumulative risk of a fuel tank explosion is 0.56 with Option 0 and 0.34 with Option 1 during the period of analysis (see Table 9). 0.22 avoided accident means that there is a 22 % chance that 167 fatalities can be avoided, which is represented as 0.22 × 167 = 37 fatalities prevented.

The aeroplane damages avoided and the accident investigation costs saved are analysed in section 1.5.3 Economic impact above.

3.2. Impacts of a false terrorist attack alert

A fuel tank explosion is initially indistinguishable from an explosion caused by a terrorist bomb in the cargo or passenger area. This section estimates whether Option 1 would be more cost-effective with the inclusion of the precautionary action benefit, based on a similar 2008 assessment by the FAA[29].

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[28] The average number is calculated by weighting the typical number of seats of each model by its share in the whole fleet.

[29] Allen A., Mastter, APO-320: Final Regulatory Evaluation, Regulatory Flexibility Analysis, International Trade Impact Assessment, And Unfunded Mandates Act Assessment for Final Rule: Fuel Tank Flammability Reduction Airbus and Boeing Airplane Fleets CFR Part 25, 121, 125, and 129. Appendix A: Benefit/Cost Analysis Incorporating Losses from Mistaking a HCTW Explosion for a Terrorist Attack. Office of Aviation Policy and Plans, Aircraft Regulatory Analysis Branch, APO-320. July, 2008, pp. 179-189.

If an aeroplane would explode, one of the first things examined would be whether the cause is terrorism or not, and the public would likely want assurances that there would not be another explosion. Public trust concerns would likely result in risk minimising decisions making by all concerned. Governments, airport operators and airlines might assume that the accident is part of a larger terrorist plot requiring immediate action to prevent danger to other air travellers.

After the 9 August 2006 late night arrest of the liquid bomb plotters in England, a large share of departures were cancelled in the following days[30]. If it takes an extended time to determine that an explosion was a fuel tank explosion, more extensive and stringent cargo requirement and more intrusive passenger screening would be mandated for all aeroplanes, not only those with high flammability central wing tank.

The cause of an on- ground aeroplane explosion could be easier to identify than an in-flight explosion, especially if the remaining wreckage cannot be easily accessed. For these reasons, the uncertainty and the associated costs are higher in the case of an in-flight explosion. The estimated risks of an in-flight and on-the-ground explosions are 80 % and 20 % respectively.

Navarro and Spancer[31] estimate that shutting down the entire air transportation network for two and a half days cost almost USD 1.5 billion in 2001 just from lost airfares and cargo shipping revenues (USD 600 million per day).

Until a terrorist act can be excluded, an immediate response would be grounding all flights to re-examine all cargo and passengers in order to make certain that there are no further terrorist bombs. It is assumed that one and a half day of grounding is a reasonable average response for an in-flight, and half day for an on-the-ground explosion.

Based on ICAO data[32], the global aviation industry has grown by 80.3% in terms of passengers, and by 83.1% in terms of passenger-kilometres in the 2001–2012[33] period (**Table 13**).

Table 13: Growth of the global aviation industry in real terms[34]

	2001	2012	Change
Passengers (millions)	1 640	2 957	180.3%
Passenger-kilometre (millions)	2 949 550	5 401 797	183.1%

Also based on ICAO data for 2012, the size of the North American airline industry in terms of passenger service is sufficiently similar to Europe in order to be used as a basis for an estimation of the European losses in case of a temporary shutdown (**Table 14**).

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30 On 10th August all international inbound flight to London Heathrow Airport were cancelled, and on 13th August still 30 per cent of the flights were cancelled to reduce pressure on security screeners.

31 Peter Navarro and Aron Spencer: September 11, 2001: Assessing the Cost of Terrorism. Milken Institute Review, Fourth Quarter 2011. http://www.milkeninstitute.org/publications/review/2001_12/16-31mr.pdf.

32 ICAO Annual Report to the Council 2010. Attachment to Appendix 1, pp 5–7. http://www.icao.int/publications/Documents/10001_en.pdf.

ICAO Annual Report to the Council 2012. Appendix 1, pp 1–3. http://www.icao.int/publications/Documents/9952_en.pdf.

33 2012 is the latest data available at the time of the analysis.

34 Scheduled services of airlines of ICAO Member States, international and domestic services.

Table 14: Comparison of North-American and European traffic (2012)[35]

Traffic	Europe		North America	
Aircraft kilometres (millions)	9 984	24.7%	13 297	32.8%
Passengers (thousands)	799 324	27.0%	810 191	27.4%
Passenger-kilometres (millions)	1 466 623	27.2%	1 452 654	26.9%

Taking into account the growth of the aviation industry in real terms (i.e. traffic) in the 2001–2012 period, and the similar size of the North-American and European market, the estimated costs of an one-day of grounding caused by an on-the-ground and in-flight explosion are EUR 420 and EUR 840 million respectively.

An one and a half-day grounding caused by an in-flight explosion is estimated to cost around EUR 1.3 billion, and the cost of a half-day grounding following an on-the-ground explosion is estimated at EUR 210 million. Weighting these values by the probability of an on-the-ground and in-flight explosion (20 % and 80 % respectively), the cost of an explosion is around EUR 1 billion (EUR 1 051 million).

The potential benefit of preventing the cost of a grounding caused by a false terrorist attack caused by a fuel tank explosion equals the number of accidents prevented multiplied by the cost of an explosion, i.e. 0.22 × EUR 1.051 billion = EUR 232.8 million.

[35] International and domestic services of ICAO Member States. Percentages express the respective share of world traffic.

Table 15: Number of aeroplanes[36] with high flammability fuel tank and no FRM (Option 0)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	1 191	208	475	230	2 104
2014	1 191	208	475	230	2 104
2015	1 191	208	475	230	2 104
2016	1 191	208	475	230	2 104
2017	1 191	208	475	230	2 104
2018	1 191	208	475	230	2 104
2019	1 191	208	475	230	2 104
2020	1 191	208	475	230	2 104
2021	1 191	208	475	230	2 104
2022	1 191	208	475	230	2 104
2023	1 191	208	475	230	2 104
2024	1 147	194	427	192	1 960
2025	1 078	173	371	146	1 768
2026	1 000	158	328	105	1 591
2027	919	140	294	84	1 437
2028	846	116	262	69	1 293
2029	779	97	228	53	1 157
2030	702	80	198	38	1 018
2031	621	68	161	33	883
2032	526	48	126	24	724
2033	421	35	64	14	534
2034	307	16	3	10	336
2035	173	9	2	0	184
2036	81	4	1	0	86
2037	0	0	0	0	0
2038	0	0	0	0	0

[36] In service and storage.

Table 16: Number of aeroplanes equipped with FRM (Option 1)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	596	104	238	115	1 052
2022	596	104	238	115	1 052
2023	596	104	238	115	1 052
2024	1 147	194	427	192	1 960
2025	1 078	173	371	146	1 768
2026	1 000	158	328	105	1 591
2027	919	140	294	84	1 437
2028	846	116	262	69	1 293
2029	779	97	228	53	1 157
2030	702	80	198	38	1 018
2031	621	68	161	33	883
2032	526	48	126	24	724
2033	421	35	64	14	534
2034	307	16	3	10	336
2035	173	9	2	0	184
2036	81	4	1	0	86
2037	0	0	0	0	0
2038	0	0	0	0	0

Table 17: Flight hours of high flammability types with Option 0

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	3 328 987	985 296	1 342 521	899 248	6 556 053
2014	3 328 987	985 296	1 342 521	899 248	6 556 053
2015	3 328 987	985 296	1 342 521	899 248	6 556 053
2016	3 328 987	985 296	1 342 521	899 248	6 556 053
2017	3 328 987	985 296	1 342 521	899 248	6 556 053
2018	3 328 987	985 296	1 342 521	899 248	6 556 053
2019	3 328 987	985 296	1 342 521	899 248	6 556 053
2020	3 328 987	985 296	1 342 521	899 248	6 556 053
2021	3 328 987	985 296	1 342 521	899 248	6 556 053
2022	3 328 987	985 296	1 342 521	899 248	6 556 053
2023	3 328 987	985 296	1 342 521	899 248	6 556 053
2024	3 206 002	918 978	1 206 856	750 677	6 082 513
2025	3 013 139	819 501	1 048 580	570 827	5 452 047
2026	2 795 120	748 446	927 046	410 526	4 881 138
2027	2 568 715	663 180	830 950	328 421	4 391 266
2028	2 364 671	549 492	740 506	269 775	3 924 444
2029	2 177 398	459 489	644 410	207 218	3 488 515
2030	1 962 174	378 960	559 619	148 571	3 049 325
2031	1 735 769	322 116	455 044	129 023	2 641 952
2032	1 470 233	227 376	356 121	93 835	2 147 565
2033	1 176 745	165 795	180 887	54 737	1 578 164
2034	858 102	75 792	8 479	39 098	981 471
2035	483 556	42 633	5 653	0	531 841
2036	226 405	18 948	2 826	0	248 179
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	60 656 890	16 228 963	21 734 711	12 894 441	111 515 005

Table 18: Flight hours of high flammability types without FRM (Option 1)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	3 328 987	985 296	1 342 521	899 248	6 556 053
2014	3 328 987	985 296	1 342 521	899 248	6 556 053
2015	3 328 987	985 296	1 342 521	899 248	6 556 053
2016	3 328 987	985 296	1 342 521	899 248	6 556 053
2017	3 328 987	985 296	1 342 521	899 248	6 556 053
2018	3 328 987	985 296	1 342 521	899 248	6 556 053
2019	3 328 987	985 296	1 342 521	899 248	6 556 053
2020	3 328 987	985 296	1 342 521	899 248	6 556 053
2021	1 664 494	492 648	671 261	449 624	3 278 027
2022	1 664 494	492 648	671 261	449 624	3 278 027
2023	1 664 494	492 648	671 261	449 624	3 278 027
2024	0	0	0	0	0
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0
2029	0	0	0	0	0
2030	0	0	0	0	0
2031	0	0	0	0	0
2032	0	0	0	0	0
2033	0	0	0	0	0
2034	0	0	0	0	0
2035	0	0	0	0	0
2036	0	0	0	0	0
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	31 625 380	9 360 312	12 753 951	8 542 860	62 282 504

Table 19: Flight hours of high flammability types equipped with FRM (Option 1)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	1 664 494	492 648	671 261	449 624	3 278 027
2022	1 664 494	492 648	671 261	449 624	3 278 027
2023	1 664 494	492 648	671 261	449 624	3 278 027
2024	3 206 002	918 978	1 206 856	750 677	6 082 513
2025	3 013 139	819 501	1 048 580	570 827	5 452 047
2026	2 795 120	748 446	927 046	410 526	4 881 138
2027	2 568 715	663 180	830 950	328 421	4 391 266
2028	2 364 671	549 492	740 506	269 775	3 924 444
2029	2 177 398	459 489	644 410	207 218	3 488 515
2030	1 962 174	378 960	559 619	148 571	3 049 325
2031	1 735 769	322 116	455 044	129 023	2 641 952
2032	1 470 233	227 376	356 121	93 835	2 147 565
2033	1 176 745	165 795	180 887	54 737	1 578 164
2034	858 102	75 792	8 479	39 098	981 471
2035	483 556	42 633	5 653	0	531 841
2036	226 405	18 948	2 826	0	248 179
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	29 031 509	6 868 650	8 980 760	4 351 581	49 232 500

Table 20 Projected number of aeroplane accidents with Option 0

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0.017	0.005	0.007	0.004	0.033
2014	0.017	0.005	0.007	0.004	0.033
2015	0.017	0.005	0.007	0.004	0.033
2016	0.017	0.005	0.007	0.004	0.033
2017	0.017	0.005	0.007	0.004	0.033
2018	0.017	0.005	0.007	0.004	0.033
2019	0.017	0.005	0.007	0.004	0.033
2020	0.017	0.005	0.007	0.004	0.033
2021	0.017	0.005	0.007	0.004	0.033
2022	0.017	0.005	0.007	0.004	0.033
2023	0.017	0.005	0.007	0.004	0.033
2024	0.016	0.005	0.006	0.004	0.030
2025	0.015	0.004	0.005	0.003	0.027
2026	0.014	0.004	0.005	0.002	0.024
2027	0.013	0.003	0.004	0.002	0.022
2028	0.012	0.003	0.004	0.001	0.020
2029	0.011	0.002	0.003	0.001	0.017
2030	0.010	0.002	0.003	0.001	0.015
2031	0.009	0.002	0.002	0.001	0.013
2032	0.007	0.001	0.002	0.000	0.011
2033	0.006	0.001	0.001	0.000	0.008
2034	0.004	0.000	0.000	0.000	0.005
2035	0.002	0.000	0.000	0.000	0.003
2036	0.001	0.000	0.000	0.000	0.001
2037	0.000	0.000	0.000	0.000	0.000
2038	0.000	0.000	0.000	0.000	0.000
Total	0.303	0.081	0.109	0.064	0.558

Table 21: Value of material damages avoided (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	61 420	18 179	24 770	16 591	120 959
2022	61 420	18 179	24 770	16 591	120 959
2023	61 420	18 179	24 770	16 591	120 959
2024	118 301	33 910	44 533	27 700	224 445
2025	111 185	30 240	38 693	21 064	201 181
2026	103 140	27 618	34 208	15 148	180 114
2027	94 786	24 471	30 662	12 119	162 038
2028	87 256	20 276	27 325	9 955	144 812
2029	80 346	16 955	23 779	7 646	128 726
2030	72 404	13 984	20 650	5 482	112 520
2031	64 050	11 886	16 791	4 761	97 488
2032	54 252	8 390	13 141	3 462	79 245
2033	43 422	6 118	6 675	2 020	58 234
2034	31 664	2 797	313	1 443	36 216
2035	17 843	1 573	209	0	19 625
2036	8 354	699	104	0	9 158
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	1 071 263	253 453	331 390	160 573	1 816 679

Table 22: Value of material damages avoided (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	44 879	13 283	18 099	12 123	88 384
2022	43 153	12 772	17 403	11 657	84 984
2023	41 493	12 281	16 733	11 208	81 716
2024	76 846	22 027	28 928	17 993	145 795
2025	69 446	18 888	24 167	13 156	125 657
2026	61 943	16 586	20 544	9 098	108 172
2027	54 736	14 132	17 707	6 998	93 573
2028	48 450	11 259	15 172	5 527	80 409
2029	42 897	9 052	12 696	4 082	68 728
2030	37 170	7 179	10 601	2 814	57 765
2031	31 617	5 867	8 289	2 350	48 123
2032	25 750	3 982	6 237	1 643	37 613
2033	19 817	2 792	3 046	922	26 577
2034	13 895	1 227	137	633	15 893
2035	7 529	664	88	0	8 281
2036	3 390	284	42	0	3 716
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	623 012	152 276	199 890	100 207	1 075 384

Table 23: Projected number of accidents avoided by FRM (Option 1)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0.000	0.000	0.000	0.000	0.000
2014	0.000	0.000	0.000	0.000	0.000
2015	0.000	0.000	0.000	0.000	0.000
2016	0.000	0.000	0.000	0.000	0.000
2017	0.000	0.000	0.000	0.000	0.000
2018	0.000	0.000	0.000	0.000	0.000
2019	0.000	0.000	0.000	0.000	0.000
2020	0.000	0.000	0.000	0.000	0.000
2021	0.007	0.002	0.003	0.002	0.015
2022	0.007	0.002	0.003	0.002	0.015
2023	0.007	0.002	0.003	0.002	0.015
2024	0.014	0.004	0.005	0.003	0.027
2025	0.014	0.004	0.005	0.003	0.025
2026	0.013	0.003	0.004	0.002	0.022
2027	0.012	0.003	0.004	0.001	0.020
2028	0.011	0.002	0.003	0.001	0.018
2029	0.010	0.002	0.003	0.001	0.016
2030	0.009	0.002	0.003	0.001	0.014
2031	0.008	0.001	0.002	0.001	0.012
2032	0.007	0.001	0.002	0.000	0.010
2033	0.005	0.001	0.001	0.000	0.007
2034	0.004	0.000	0.000	0.000	0.004
2035	0.002	0.000	0.000	0.000	0.002
2036	0.001	0.000	0.000	0.000	0.001
2037	0.000	0.000	0.000	0.000	0.000
2038	0.000	0.000	0.000	0.000	0.000
Total	0.131	0.031	0.040	0.020	0.222

Table 24: Value of accident investigation costs saved (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	37 451	11 085	15 103	10 117	73 756
2022	37 451	11 085	15 103	10 117	73 756
2023	37 451	11 085	15 103	10 117	73 756
2024	72 135	20 677	27 154	16 890	136 857
2025	67 796	18 439	23 593	12 844	122 671
2026	62 890	16 840	20 859	9 237	109 826
2027	57 796	14 922	18 696	7 389	98 803
2028	53 205	12 364	16 661	6 070	88 300
2029	48 991	10 339	14 499	4 662	78 492
2030	44 149	8 527	12 591	3 343	68 610
2031	39 055	7 248	10 238	2 903	59 444
2032	33 080	5 116	8 013	2 111	48 320
2033	26 477	3 730	4 070	1 232	35 509
2034	19 307	1 705	191	880	22 083
2035	10 880	959	127	0	11 966
2036	5 094	426	64	0	5 584
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	653 209	154 545	202 067	97 911	1 107 731

Table 25: Value of accident investigation costs saved (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	27 365	8 099	11 036	7 392	53 892
2022	26 313	7 788	10 611	7 108	51 820
2023	25 301	7 488	10 203	6 834	49 827
2024	46 858	13 431	17 639	10 972	88 899
2025	42 345	11 517	14 736	8 022	76 620
2026	37 770	10 114	12 527	5 547	65 958
2027	33 376	8 617	10 797	4 267	57 057
2028	29 543	6 865	9 251	3 370	49 030
2029	26 157	5 520	7 741	2 489	41 907
2030	22 665	4 377	6 464	1 716	35 222
2031	19 279	3 578	5 054	1 433	29 343
2032	15 701	2 428	3 803	1 002	22 935
2033	12 084	1 703	1 857	562	16 206
2034	8 473	748	84	386	9 691
2035	4 591	405	54	0	5 049
2036	2 067	173	26	0	2 266
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	379 886	92 851	121 884	61 102	655 722

Table 26: Increased fuel consumption due to FRM (US gallons)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	974 274	288 360	392 907	263 177	1 918 718
2022	974 274	288 360	392 907	263 177	1 918 718
2023	974 274	288 360	392 907	263 177	1 918 718
2024	1 876 561	537 903	706 406	439 392	3 560 261
2025	1 763 672	479 676	613 762	334 121	3 191 232
2026	1 636 060	438 086	542 625	240 292	2 857 064
2027	1 503 539	388 177	486 378	192 234	2 570 328
2028	1 384 107	321 633	433 439	157 906	2 297 084
2029	1 274 491	268 951	377 191	121 290	2 041 923
2030	1 148 514	221 816	327 560	86 963	1 784 853
2031	1 015 993	188 543	266 350	75 520	1 546 407
2032	860 567	133 089	208 448	54 924	1 257 028
2033	688 781	97 044	105 878	32 039	923 743
2034	502 270	44 363	4 963	22 885	574 482
2035	283 038	24 954	3 309	0	311 301
2036	132 521	11 091	1 654	0	145 266
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	16 992 935	4 020 409	5 256 684	2 547 099	28 817 127

Table 27: Cost of increased fuel consumption due to FRM (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	2 274 923	673 320	917 436	614 517	4 480 196
2022	2 274 923	673 320	917 436	614 517	4 480 196
2023	2 274 923	673 320	917 436	614 517	4 480 196
2024	4 381 757	1 256 000	1 649 453	1 025 977	8 313 187
2025	4 118 164	1 120 041	1 433 131	780 170	7 451 507
2026	3 820 189	1 022 928	1 267 027	561 081	6 671 226
2027	3 510 754	906 392	1 135 689	448 865	6 001 700
2028	3 231 880	751 010	1 012 076	368 710	5 363 678
2029	2 975 928	628 000	880 738	283 212	4 767 878
2030	2 681 773	517 938	764 852	203 058	4 167 621
2031	2 372 338	440 247	621 925	176 340	3 610 850
2032	2 009 420	310 763	486 724	128 247	2 935 153
2033	1 608 300	226 598	247 225	74 811	2 156 933
2034	1 172 798	103 588	11 589	53 436	1 341 411
2035	660 893	58 268	7 726	0	726 887
2036	309 435	25 897	3 863	0	339 195
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	39 678 398	9 387 629	12 274 325	5 947 460	67 287 812

Table 28: Cost of increased fuel consumption due to FRM (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	1 662 264	491 988	670 361	449 022	3 273 635
2022	1 598 331	473 065	644 578	431 752	3 147 726
2023	1 536 856	454 871	619 787	415 146	3 026 660
2024	2 846 306	815 874	1 071 453	666 455	5 400 088
2025	2 572 193	699 574	895 130	487 292	4 654 189
2026	2 294 307	614 344	760 944	336 971	4 006 565
2027	2 027 373	523 419	655 832	259 208	3 465 832
2028	1 794 548	417 009	561 970	204 732	2 978 260
2029	1 588 872	335 294	470 233	151 209	2 545 609
2030	1 376 751	265 896	392 654	104 245	2 139 545
2031	1 171 053	217 319	307 000	87 046	1 782 417
2032	953 756	147 501	231 020	60 872	1 393 148
2033	734 007	103 416	112 830	34 143	984 396
2034	514 663	45 458	5 085	23 450	588 656
2035	278 867	24 587	3 260	0	306 714
2036	125 546	10 507	1 567	0	137 620
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	23 075 693	5 640 121	7 403 705	3 711 542	39 831 061

Table 29: Maintenance and fuel costs (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	7 984 621	4 892 077	11 171 811	4 390 549	28 439 058
2022	7 984 621	4 892 077	11 171 811	4 390 549	28 439 058
2023	7 984 621	4 892 077	11 171 811	4 390 549	28 439 058
2024	15 379 278	9 125 606	20 085 741	7 330 307	51 920 932
2025	14 454 108	8 137 783	17 451 545	5 574 088	45 617 523
2026	13 408 263	7 432 195	15 428 860	4 008 762	40 278 079
2027	12 322 194	6 585 489	13 829 527	3 207 009	35 944 219
2028	11 343 391	5 456 548	12 324 272	2 634 329	31 758 540
2029	10 445 037	4 562 803	10 724 939	2 023 470	27 756 249
2030	9 412 601	3 763 136	9 313 763	1 450 790	23 940 290
2031	8 326 531	3 198 666	7 573 312	1 259 897	20 358 406
2032	7 052 746	2 257 882	5 926 940	916 288	16 153 857
2033	5 644 879	1 646 372	3 010 509	534 502	10 836 262
2034	4 116 337	752 627	141 118	381 787	5 391 869
2035	2 319 630	423 353	94 078	0	2 837 061
2036	1 086 069	188 157	47 039	0	1 321 265
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	139 264 925	68 206 848	149 467 077	42 492 874	399 431 725

Table 30: Maintenance and fuel costs (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	5 834 284	3 574 593	8 163 133	3 208 131	20 780 141
2022	5 609 889	3 437 109	7 849 166	3 084 741	19 980 905
2023	5 394 124	3 304 912	7 547 275	2 966 097	19 212 409
2024	9 990 086	5 927 820	13 047 314	4 761 628	33 726 847
2025	9 027 993	5 082 835	10 900 184	3 481 559	28 492 571
2026	8 052 655	4 463 583	9 266 173	2 407 558	24 189 970
2027	7 115 760	3 802 956	7 986 207	1 851 968	20 756 891
2028	6 298 582	3 029 827	6 843 231	1 462 749	17 634 390
2029	5 576 691	2 436 118	5 726 133	1 080 347	14 819 288
2030	4 832 177	1 931 894	4 781 437	744 797	12 290 304
2031	4 110 210	1 578 951	3 738 400	621 920	10 049 482
2032	3 347 533	1 071 687	2 813 177	434 909	7 667 306
2033	2 576 249	751 383	1 373 957	243 940	4 945 528
2034	1 806 387	330 278	61 927	167 541	2 366 133
2035	978 780	178 636	39 697	0	1 197 113
2036	440 647	76 340	19 085	0	536 072
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	80 992 046	40 978 922	90 156 496	26 517 886	238 645 350

Table 31: Total costs of retrofit (Euros undiscounted)

Year	Airbus SA	Airbus WB	Boeing SA	Boeing WB	Total
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	151 723 433	57 321 077	68 498 374	62 364 924	339 907 808
2022	7 984 621	4 892 077	11 171 811	4 390 549	28 439 058
2023	7 984 621	4 892 077	11 171 811	4 390 549	28 439 058
2024	153 807 840	58 025 731	71 619 303	55 726 307	339 179 182
2025	14 454 108	8 137 783	17 451 545	5 574 088	45 617 523
2026	13 408 263	7 432 195	15 428 860	4 008 762	40 278 079
2027	12 322 194	6 585 489	13 829 527	3 207 009	35 944 219
2028	11 343 391	5 456 548	12 324 272	2 634 329	31 758 540
2029	10 445 037	4 562 803	10 724 939	2 023 470	27 756 249
2030	9 412 601	3 763 136	9 313 763	1 450 790	23 940 290
2031	8 326 531	3 198 666	7 573 312	1 259 897	20 358 406
2032	7 052 746	2 257 882	5 926 940	916 288	16 153 857
2033	5 644 879	1 646 372	3 010 509	534 502	10 836 262
2034	4 116 337	752 627	141 118	381 787	5 391 869
2035	2 319 630	423 353	94 078	0	2 837 061
2036	1 086 069	188 157	47 039	0	1 321 265
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	421 432 300	169 535 973	258 327 202	148 863 249	998 158 725

Table 32: Total costs of retrofit (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	110 862 827	41 883 950	50 051 091	45 569 439	248 367 306
2022	5 609 889	3 437 109	7 849 166	3 084 741	19 980 905
2023	5 394 124	3 304 912	7 547 275	2 966 097	19 212 409
2024	99 910 640	37 692 408	46 522 534	36 198 747	220 324 329
2025	9 027 993	5 082 835	10 900 184	3 481 559	28 492 571
2026	8 052 655	4 463 583	9 266 173	2 407 558	24 189 970
2027	7 115 760	3 802 956	7 986 207	1 851 968	20 756 891
2028	6 298 582	3 029 827	6 843 231	1 462 749	17 634 390
2029	5 576 691	2 436 118	5 726 133	1 080 347	14 819 288
2030	4 832 177	1 931 894	4 781 437	744 797	12 290 304
2031	4 110 210	1 578 951	3 738 400	621 920	10 049 482
2032	3 347 533	1 071 687	2 813 177	434 909	7 667 306
2033	2 576 249	751 383	1 373 957	243 940	4 945 528
2034	1 806 387	330 278	61 927	167 541	2 366 133
2035	978 780	178 636	39 697	0	1 197 113
2036	440 647	76 340	19 085	0	536 072
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	275 941 143	111 052 867	165 519 674	100 316 313	652 829 996

Table 33: Increased CO_2 emission due to FRM (metric tons)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	9 378	2 776	3 782	2 533	18 469
2022	9 378	2 776	3 782	2 533	18 469
2023	9 378	2 776	3 782	2 533	18 469
2024	18 063	5 178	6 800	4 229	34 270
2025	16 976	4 617	5 908	3 216	30 718
2026	15 748	4 217	5 223	2 313	27 501
2027	14 472	3 736	4 682	1 850	24 741
2028	13 323	3 096	4 172	1 520	22 111
2029	12 268	2 589	3 631	1 167	19 655
2030	11 055	2 135	3 153	837	17 180
2031	9 780	1 815	2 564	727	14 885
2032	8 283	1 281	2 006	529	12 100
2033	6 630	934	1 019	308	8 892
2034	4 835	427	48	220	5 530
2035	2 724	240	32	0	2 996
2036	1 276	107	16	0	1 398
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	163 567	38 699	50 599	24 517	277 382

Table 34: Shadow price of increased CO_2 emissions (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	600 190	177 641	242 046	162 127	1 182 005
2022	600 190	177 641	242 046	162 127	1 182 005
2023	600 190	177 641	242 046	162 127	1 182 005
2024	1 156 034	331 369	435 173	270 682	2 193 259
2025	1 086 491	295 499	378 101	205 831	1 965 923
2026	1 007 876	269 878	334 278	148 029	1 760 062
2027	926 238	239 132	299 628	118 424	1 583 422
2028	852 663	198 138	267 015	97 276	1 415 093
2029	785 136	165 685	232 364	74 720	1 257 904
2030	884 412	170 809	252 237	66 966	1 374 424
2031	782 364	145 187	205 102	58 154	1 190 808
2032	662 679	102 485	160 515	42 294	967 973
2033	530 395	74 729	81 531	24 672	711 327
2034	386 773	34 162	3 822	17 623	442 379
2035	217 953	19 216	2 548	0	239 717
2036	102 047	8 540	1 274	0	111 862
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	11 181 633	2 587 754	3 379 727	1 611 054	18 760 167

Table 35: Shadow price of increased CO_2 emissions (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	438 553	129 801	176 861	118 465	863 680
2022	421 686	124 808	170 058	113 909	830 461
2023	405 467	120 008	163 518	109 528	798 520
2024	750 938	215 251	282 680	175 830	1 424 699
2025	678 619	184 568	236 161	128 562	1 227 910
2026	605 304	162 082	200 759	88 903	1 057 048
2027	534 880	138 093	173 027	68 387	914 387
2028	473 454	110 019	148 264	54 014	785 751
2029	419 190	88 460	124 061	39 893	671 605
2030	454 033	87 689	129 492	34 378	705 592
2031	386 197	71 669	101 244	28 707	587 816
2032	314 535	48 644	76 187	20 075	459 441
2033	242 065	34 105	37 210	11 260	324 640
2034	169 729	14 991	1 677	7 733	194 131
2035	91 967	8 108	1 075	0	101 150
2036	41 403	3 465	517	0	45 385
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	6 428 021	1 541 761	2 022 792	999 642	10 992 216

Table 36: Cost of retrofit (Euros undiscounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	143 738 813	52 429 000	57 326 563	57 974 375	311 468 750
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	138 428 563	48 900 125	51 533 563	48 396 000	287 258 250
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0
2029	0	0	0	0	0
2030	0	0	0	0	0
2031	0	0	0	0	0
2032	0	0	0	0	0
2033	0	0	0	0	0
2034	0	0	0	0	0
2035	0	0	0	0	0
2036	0	0	0	0	0
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	282 167 375	101 329 125	108 860 125	106 370 375	598 727 000

Table 37: Cost of retrofit (Euros discounted)

Year	Airbus		Boeing		Total
	SA	WB	SA	WB	
2013	0	0	0	0	0
2014	0	0	0	0	0
2015	0	0	0	0	0
2016	0	0	0	0	0
2017	0	0	0	0	0
2018	0	0	0	0	0
2019	0	0	0	0	0
2020	0	0	0	0	0
2021	105 028 542	38 309 357	41 887 958	42 361 308	227 587 165
2022	0	0	0	0	0
2023	0	0	0	0	0
2024	89 920 555	31 764 589	33 475 220	31 437 119	186 597 482
2025	0	0	0	0	0
2026	0	0	0	0	0
2027	0	0	0	0	0
2028	0	0	0	0	0
2029	0	0	0	0	0
2030	0	0	0	0	0
2031	0	0	0	0	0
2032	0	0	0	0	0
2033	0	0	0	0	0
2034	0	0	0	0	0
2035	0	0	0	0	0
2036	0	0	0	0	0
2037	0	0	0	0	0
2038	0	0	0	0	0
Total	194 949 097	70 073 946	75 363 177	73 798 427	414 184 646