European Union Aviation Safety Agency

Notice of Proposed Amendment 2020-05

Tyre pressure monitoring

RMT.0586

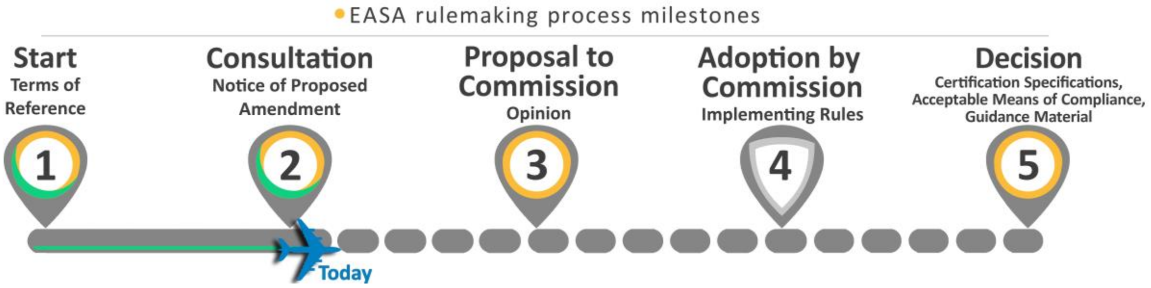
EXECUTIVE SUMMARY

The objective of this NPA is to decrease the risk of a hazardous or catastrophic tyre failure of a large aeroplane that is caused by inadequate tyre inflation pressure.

This NPA proposes to amend CS-25 to require applicants to provide a means to ensure that no tyre is below its minimum serviceable inflation pressure during operation. This can be achieved either by providing a task in the instructions for continued airworthiness (ICA) that requires operators to perform tyre pressure checks at a suitable time interval (i.e. daily or at another substantiated interval), or by installing a tyre pressure monitoring system that alerts the flight crew in the case of a tyre with an unsafe pressure. It also proposes to amend Part-26 and CS-26 to require the same objective to be implemented by operators of large aeroplanes, i.e. either by including in the aeroplane maintenance programme (AMP) tyre inflation pressure checks at a suitable time interval, or by installing a tyre pressure monitoring system.

The proposed changes are expected to increase safety without any significant economic impact, and with no environmental or social impact.

Action area:	Design, production and maintenance improvements		
Affected rules:	CS-25, Part-26, CS-26		
Affected stakeholders:	Large aeroplane manufacturers and their suppliers; operators of large aeroplanes; maintenance organisations.		
Driver:	Safety	**Rulemaking group:**	Yes
Impact assessment:	Yes	**Rulemaking Procedure:**	Standard



30.5.2017	5.3.2020	2021/Q1 (Part-26) + Decision CS-25	2022/Q3 (Part-26)	2022/Q3 (CS-26)

Table of contents

1. About this NPA

1.1. How this NPA was developed

The European Union Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EU) 2018/1139[1] (the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the European Plan for Aviation Safety (EPAS) 2020-2024[3] under rulemaking task (RMT).0586. The text of this NPA has been developed by EASA based on the input of the Rulemaking Group (RMG) for RMT.0586. It is hereby submitted to all interested parties[4] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[5].

The deadline for submission of comments is **6 June 2020.**

1.3. The next steps

Based on the comments received, EASA will develop a decision that amends the Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes (CS-25).

EASA will also develop an opinion that contains the proposed amendments to Annex I (Part-26) to Regulation (EU) 2015/640[6].

The opinion will be submitted to the European Commission, which will use it as a technical basis in order to prepare an EU regulation.

Following the adoption of the regulation, EASA will issue a decision that contains the related Certification Specifications and Guidance Material for Additional airworthiness specifications for operations (CS-26).

The comments received on this NPA and the EASA responses to them will be reflected in a comment-response document (CRD). The CRD will be published on the EASA website[7].

---

1 Regulation (EU) 2018/1139 of the European Parliament and of the Council of 4 July 2018 on common rules in the field of civil aviation and establishing a European Union Aviation Safety Agency, and amending Regulations (EC) No 2111/2005, (EC) No 1008/2008, (EU) No 996/2010, (EU) No 376/2014 and Directives 2014/30/EU and 2014/53/EU of the European Parliament and of the Council, and repealing Regulations (EC) No 552/2004 and (EC) No 216/2008 of the European Parliament and of the Council and Council Regulation (EEC) No 3922/91 (OJ L 212, 22.8.2018, p. 1) (https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1535612134845&uri=CELEX:32018R1139).

2 EASA is bound to follow a structured rulemaking process as required by Article 115(1) of Regulation (EU) 2018/1139. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

3 https://www.easa.europa.eu/document-library/general-publications?publication_type%5B%5D=2467

4 In accordance with Article 115 of Regulation (EU) 2018/1139 and Articles 6(3) and 7 of the Rulemaking Procedure.

5 In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

6 Commission Regulation (EU) 2015/640 of 23 April 2015 on additional airworthiness specifications for a given type of operations and amending Regulation (EU) No 965/2012.

7 https://www.easa.europa.eu/document-library/comment-response-documents

2. In summary — why and what

2.1. Why we need to change the rules — issue/rationale

Incorrect tyre pressure, and, in particular, the under-inflation of tyres, is a contributing factor to tyre- and wheel-failure-related accidents or incidents of large aeroplanes. These kinds of occurrences have continued to arise, despite the various actions taken by industry and regulators over the last 40 years. These actions include improvements in tyre maintenance practices, numerous communications on good practices for tyre pressure checks, and improvements in tyre and wheel robustness. Actions have also been taken to mitigate the severity of occurrences, i.e. the improvement of the protection of the aeroplanes against the effects of tyre failures. However, the review of the reported occurrences indicates that a further reduction in the risk of a tyre failure is needed.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 1 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Section 2.1.

The specific objective is to decrease the risk of hazardous or catastrophic tyre failures of large aeroplanes that are caused by inadequate tyre inflation pressures. This is to be achieved through improvements that will ensure that the tyre inflation pressure remains within the safe levels defined by the aeroplane manufacturer.

2.3. How we want to achieve it — overview of the proposals

It is proposed to amend CS-25 to require applicants to provide a means to ensure that no tyre is below its minimum serviceable inflation pressure during operation. This can be achieved either by providing a task in the instructions for continued airworthiness (ICA) that requires operators to perform tyre pressure checks at a suitable time interval (i.e. daily or at another substantiated interval), or by installing a tyre pressure monitoring system that alerts the flight crew whenever a tyre inflation pressure is unsafe (i.e. below the minimum serviceable inflation pressure).

As the amendment to CS-25 would only address new designs of large aeroplanes, it is also proposed to amend Part-26 and CS-26 to require the same objective to be implemented by operators of large aeroplanes. In this case, this can be achieved either by including tasks in the aeroplane maintenance programme (AMP) to perform tyre inflation pressure checks at a suitable time interval, or by installing a tyre pressure monitoring system.

2.4. What are the expected benefits and drawbacks of the proposals

The proposals would ensure that tyre inflation pressures are checked at an appropriate time interval, thereby minimising the risk of operating with an unsafe tyre inflation pressure. This would improve safety (by reducing the number of tyre failures) without any significant economic impact, and with no environmental or social impact. The proposals are simple to put in place and do not mandate design changes.

For the full impact assessment of the alternative options, please refer to Chapter 4.

3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

- deleted text is ~~struck through~~;
- new or amended text is highlighted in blue;
- an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft certification specifications and acceptable means of compliance for large aeroplanes (CS-25) (Draft EASA decision)

CS 25.733 Tyres

(…)

(f) A means shall be provided to ensure that no tyre is below its minimum serviceable inflation pressure during operation, by either:

(1) providing a task in the instructions for continued airworthiness that requires tyre inflation pressure checks to be performed at a suitable time interval, or

(2) installing an on-board tyre pressure monitoring system that alerts the flight crew whenever a tyre inflation pressure is below the minimum serviceable inflation pressure.

AMC 25.733(f) Tyre inflation pressure check

When demonstrating compliance with CS 25.733(f), the applicant should take into account the following elements:

1. 'Minimum serviceable inflation pressure' means a tyre inflation pressure specified by the aeroplane type certificate holder below which damage to the tyre, potentially leading to a tyre failure, may occur.

2. 'Suitable time interval' is the maximum time interval between two consecutive tyre inflation pressure checks. Checks should be conducted daily in order to ensure that the elapsed clock time between two consecutive tyre inflation pressure checks does not exceed 48 hours. Time intervals longer than 48 hours may be used if they are substantiated and agreed by EASA. This substantiation should at least include an analysis of the expected loss of tyre pressure during operation, taking into account the environmental and operational factors. If available, statistical data related to pressure losses gathered from the service experience of aeroplanes equipped with equivalent wheel designs should also be used. The substantiation should be made in cooperation with the tyre manufacturer(s).

3. If an on-board tyre pressure monitoring system is installed, its development assurance level should be commensurate with the potential consequences of an alert not being provided, as well as with the consequences of false alerts. If the system includes the indication of tyre pressure levels, the consequence of a false indication should also be taken into account. The assessment of these consequences should include the effects of the failure of one or more tyres (including simultaneous tyre failures) that may be caused by the operation of the aeroplane with under-inflated tyres.

Instructions for continued airworthiness should be provided to ensure that the tyre pressure monitoring system is calibrated at an appropriate time interval.

Rationale:

The applicant can choose between two options to reach the objective of the rule, i.e. to ensure that the aeroplane is operated with tyres that are inflated at safe pressure levels.

Regarding tyre inflation pressure checks, a daily check has long been recommended by various industry stakeholders and aviation authorities as a safe standard owing to the possible loss of tyre pressure during operation. The inflation retention standard of (European) Technical Standard Order (E)TSO-C62e ('Aircraft Tyres') allows a loss of tyre pressure of up to 5 % of the initial pressure after 24 hours. Therefore, this interval should be considered as a baseline. If an applicant wishes to provide a longer interval, this must be properly substantiated and agreed with EASA.

It is also possible to rely on an on-board system that is able to alert the flight crew when a tyre pressure falls below the minimum serviceable inflation pressure.

3.2. Draft regulation on additional airworthiness specifications for a given type of operations (Part-26) (Draft EASA Opinion)

CONTENTS

(…)

SUBPART B

LARGE AEROPLANES

26.201 Tyre inflation pressure

Operators of large aeroplanes shall ensure that no tyre is below its minimum serviceable inflation pressure during operation by either:

(a) incorporating a task in the aeroplane maintenance programme (AMP) requiring operators to perform tyre inflation pressure checks at a suitable time interval, or

(b) installing an on-board tyre pressure monitoring system that alerts the flight crew whenever a tyre inflation pressure is below the minimum serviceable inflation pressure.

3.3. Draft additional airworthiness specifications for operations (CS-26) (Draft EASA decision)

CONTENTS

Introduce the term 'point' throughout CS-26 when referring to a Part-26 paragraph, and create CS 26.201 as follows:

Book 1

SUBPART B - LARGE AEROPLANES

CS 26.50 Seats, berths, safety belts, and harnesses

Compliance with point 26.50 of Part-26 is demonstrated by (…)

CS 26.60 Emergency landing — dynamic conditions

Compliance with point 26.60 of Part-26 is demonstrated by (…)

CS 26.100 Location of emergency exits

Compliance with point 26.100 of Part-26 is demonstrated by (…)

CS 26.105 Emergency exit access

Compliance with point 26.105 of Part-26 is demonstrated by (…)

CS 26.110 Emergency exit markings

Compliance with point 26.110 of Part-26 is demonstrated by (…)

CS 26.120 Interior emergency lighting and emergency light operation

Compliance with point 26.120 of Part-26 is demonstrated by (…)

(d)(1)

(i) 10 seats or more, each passenger emergency exit locator sign and marking sign required by point 26.110(d) of Part-26 has red letters at least 38 mm (1 ½ inches) high on an illuminated white background, and has an area of at least 135 cm2 (21 square inches) excluding the letters. The lighted background-to-letter contrast is at least 10:1. The letter height to stroke-width ratio ~~are~~is not more than 7:1 nor less than 6:1. These signs are internally electrically illuminated with a background brightness of at least 86 cd/m2 (25 foot-lamberts) and a high-to-low background contrast no greater than 3:1. Other passenger emergency exit signs required by point 26.110(d) of Part-26 (…)

(ii) 9 seats or less, passenger emergency exit signs, that are required by point 26.110(d) of Part-26(…)

(e) Each sign required by point 26.120 of Part-26(…)

CS 26.150 Compartment interiors

Compliance with point 26.150 of Part-26 is demonstrated by (…)

(a) Upon any major replacement of any individual group of components as specified in Appendix F, Part I, sub-paragraph (a)(1)(i), such as interior ceiling panels, wall panels, etc., this individual group of components complies with Appendix F, Part I of this CS-26.(…)

CS 26.155 Flammability of cargo compartment liners

Compliance with point 26.155 of Part-26 is demonstrated by (…)

CS 26.156 Thermal/acoustic insulation materials

(a) Compliance with point 26.156(a) of Part-26 is demonstrated by complying with CS 25.856(a), or its equivalent.

(b) Compliance with point 26.156(b) of Part-26 is demonstrated by complying with CS 25.856(a), or its equivalent.

(c) Compliance with point 26.156(c) of Part-26 is demonstrated by complying with CS 25.856(b), or its equivalent.

CS 26.160 Lavatory fire protection

Compliance with point 26.160 of Part-26 is demonstrated by (…)

CS 26.170 Fire extinguishers

Compliance with point 26.170 of Part-26 is demonstrated by (…)

CS 26.200 Landing gear aural warning

Compliance with point 26.200 of Part-26 is demonstrated by (…)

CS 26.201 Tyre inflation pressure

Compliance with point 26.201 of Part-26 is demonstrated by complying with CS 25.733(f) or its equivalent, or with the following:

(a) 'Minimum serviceable inflation pressure' means a tyre inflation pressure specified by the aeroplane type certificate holder, below which damage to the tyre, potentially leading to tyre failure, may occur.

(b) 'Suitable time interval' is the maximum time interval between two consecutive tyre inflation pressure checks. These checks should be conducted daily in order to ensure that the elapsed clock time between two consecutive tyre inflation pressure checks does not exceed 48 hours. Time intervals longer than 48 hours may be used if they are substantiated and agreed by the competent authority. This substantiation at least includes an analysis of the expected loss of tyre pressure during operation, taking into account environmental and operational factors. If available, statistical data related to pressure losses gathered from the service experience of aeroplanes equipped with equivalent wheel designs is also used. The substantiation is made in cooperation with the tyre manufacturer(s). The time interval does not exceed the value provided by the type certificate holder in the instructions for continued airworthiness.

(c) If an on-board tyre pressure monitoring system is installed, its development assurance level should be commensurate with the potential consequences of an alert not being provided, as well as with the consequences of false alerts. If the system includes the indication of tyre pressure levels, the consequences of a false indication is also taken into account. The assessment of these consequences includes the effects of the failure of one or more tyres (including simultaneous tyre failures) that may be caused by the operation of the aeroplane with under-inflated tyres.

Tasks are included in the aeroplane maintenance programme (taking into account the instructions for continued airworthiness provided by the design approval holder) to ensure that the tyre pressure monitoring system is calibrated at an appropriate time interval.

SUBPART C — LARGE ROTORCRAFT

CS 26.400 Fire extinguishers

Compliance with point 26.400 of Part-26 is demonstrated by (…)

Book 2

SUBPART B - LARGE AEROPLANES

GM1 26.156(a) Insulation materials installed as replacement

The requirement of point 26.156(a) of Part-26 is applicable to (…)

Rationale:

The proposed changes to Part-26 (new point 26.201) and CS-26 (new CS 26.201) are consistent with the proposed change to CS-25. Operators must therefore ensure that their aeroplanes are operated with tyres that are inflated to safe pressures by either including adequate tyre pressure check tasks in their maintenance programme, or by installing a tyre pressure monitoring system. Regarding tyre pressure check intervals, operators would have the possibility to agree on an interval that is longer than a daily check with their competent authority after proper substantiation; however, this interval must not exceed the interval provided by the TCH in the ICA.

The proposal does not mandate a design change (as installing a TPMS is optional) and it would possibly only require an update of the tyre pressure check time interval in the maintenance programme. Given the simplicity of this action, it is not deemed necessary to provide an applicability date with a transition period.

Also, an editorial change is made throughout CS-26: when a reference is made to a paragraph of Part-26, the term 'point' should be used consistently with Regulation (EU) 2015/640.

4. Impact assessment (IA)

4.1. What is the issue

Incorrect tyre pressure, in particular under-inflation, is a contributing factor to tyre- and wheel-failure-related accidents or incidents of large aeroplanes. These kinds of occurrences have continued to arise despite the various actions taken by industry and regulators over the last 40 years. These actions include improvements in tyre maintenance practices, numerous communications on good practices for tyre pressure checks, improvements in tyre and wheel robustness, and improvements in the protection of the aeroplane against the effects of tyre failures.

It is widely recognised that ensuring the correct aeroplane tyre inflation pressure is the most important tyre-related factor for safe operation. Operation of an aeroplane with under-inflated tyres can lead to damage to the aeroplane tyres and cause tyre break-up, either directly or indirectly. On a multi-wheel assembly, an under-inflated or burst tyre can lead to the failure of the axle companion tyre.

In general, aeroplane tyre/wheel assemblies have several possible leak paths (in the order of 10). Under-inflation of a single tyre (even a significant under-inflation) on a multi-wheel assembly is nearly impossible to detect by a visual check (e.g. during a pilot preflight check), because the correctly inflated tyre (axle companion) would carry the load and would therefore prevent the flattening of the under-inflated tyre.

Although tyre over-inflation occurs less frequently, it is known to cause wheel fatigue issues. The resulting failure mode is a wheel tube well fatigue crack, which, if undetected during a tyre change or wheel overhaul, may result in a loss of tyre pressure.

4.1.1. Tyre pressure legal framework, industry practices, and previous actions taken to mitigate the issue

4.1.1.1 Legal framework

Tyre pressure loss:

The inflation retention standard of (E)TSO-C62e ('Aircraft Tyres') allows a loss of tyre pressure up to 5 % of the initial pressure after 24 hours.

Tyre pressure check:

Part-M (Annex I to Regulation (EU) No 1321/2014), point M.A.302(d) requires the aircraft maintenance programme (AMP) to be established in compliance with:

'(i) instructions issued by the competent authority;

(ii) instructions for continuing airworthiness:

- — issued by the holders of the type-certificate, restricted type-certificate, supplemental type-certificate, major repair design approval, ETSO authorisation or any other relevant approval issued under Regulation (EU) No 748/2012 and its Annex I (Part-21), and
- — included in the certification specifications referred to in point 21A.90B or 21A.431B of Annex I (Part-21) to Regulation (EU) No 748/2012, if applicable;

(iii) additional or alternative instructions proposed by the owner or the continuing airworthiness management organisation once approved in accordance with point M.A.302, except for intervals of safety-related tasks referred in point (e), which may be escalated, subject to sufficient reviews carried out in accordance with point (g) and only when subject to direct approval in accordance with point M.A.302(b).'

Intervals adopted in maintenance review board reports (MRBRs) (and then reflected in the AMM/MPD) are established taking into account the inputs and experience of operators, manufacturers, and authorities, the goal being to ensure an efficient and cost-effective maintenance programme. As tyre pressure checks are not a candidate certification maintenance requirement (CMR), the process makes it possible to agree tyre pressure check intervals which are longer than with the recommended daily check. Furthermore, operators may deviate from the values provided in the ICA when they develop their own AMP, subject to approval by the competent authority.

In addition, it has been evident that the MRB process typically does not classify a tyre failure as a safety item. Some MRB reports may not provide tasks for tyre pressure checks (as was found on some aeroplanes). Also, it is notable that some in-service aeroplanes have been certified without using the MRB process.

4.1.1.2 Industry practice

Tyre pressure check:

A daily pressure check has been recommended for a long time by various stakeholders and communication means (refer to 4.1.1.3), however, this remains only a recommendation. There are variations in the way large aeroplanes have their tyres checked. Some operators adhere to a daily pressure check, but some other operators use longer time intervals. Although some of them have not faced major safety issues, in some cases, pressure checks have been performed with an interval that was too long, leading to operation with inadequate tyre pressure levels and to reported incidents or accidents, including fatal ones.

Aircraft maintenance manuals (AMM) or maintenance planning documents (MPDs) are not harmonised, and provide different pressure check intervals depending on the type of aeroplane/manufacturer. It is also acknowledged, for instance, that some MPDs (or for some aeroplanes, the AMM chapter providing the task schedule interval) show a given value (e.g. 72 hours), but in the AMM chapter detailing the maintenance task instructions, a recommendation is provided for a daily pressure check.

On-board integrated tyre pressure monitoring systems (OBTPMSs) and ground tyre pressure indication systems (GTPISs) have been developed, certified and are available on various types of large aeroplanes. These systems are not mandated by EASA or FAA regulations, so they are therefore optional, and not all aeroplanes are equipped with them. Refer to 4.1.1.3 i) for more details.

Tyre pressure loss:

In practice, the magnitude of 'normal' tyre pressure losses varies between large aeroplane types. A 1-2 % pressure loss per day appears to be a common trend on large transport aeroplanes, which corresponds to the typical specification added by some aeroplane manufacturers on top of the specifications of (E)TSO C62e.

4.1.1.3 Previous actions to mitigate the issue

Various actions have already been taken over the years to improve tyre maintenance (in particular, tyre inflation), to increase the robustness of wheels and tyres, and to mitigate the consequences of wheel and tyre failures. These actions are summarised below

i) Actions taken to improve tyre maintenance or detect inadequate tyre inflation
   (1) Industry

(a) Journal articles published to present state-of-the-art practices and recommendations;
(b) Wide distribution of tyre manufacturer 'care & service manuals';
(c) Less formal best practice leaflets;
(d) Training activities with tyre customers;
(e) Audits of the tyre customers;
(f) Regular operators seminars at tyre manufacturers' premises;
(g) Dedicated communications and/or reminders each time there is an incident showing that the tyre pressure was not properly controlled;
(h) Cooperation between tyre manufacturers and aeroplane manufacturers in developing tyre maintenance recommendations;
(i) An airframer service letter that highlights the potential consequences of incorrect tyre inflation and recommends tyre pressure checks 'as frequently as is reasonably possible';
(j) On-board integrated tyre pressure monitoring systems (OBTPMSs) have been developed, certified and are available on various types of large aeroplanes. An OBTPMS is considered to be a useful safety net which can detect and alert the crew of unsafe tyre inflation conditions. OBTPMSs are not mandated by EASA or FAA regulations, and therefore not all aeroplanes are equipped with OBTPMSs.
(k) Ground tyre pressure indication systems (GTPISs) are available for some aeroplanes. These are systems which can indicate a pressure level below the minimum serviceable level on any one of the tyres on the ground before the dispatch of the aeroplane. Such systems vary in their designs from ones that provide simple visual indications on the affected wheel to more sophisticated systems using wheel remote data transmitters coupled with electronic equipment used by personnel:
  — Inflation valves with integrated dial gauges are available as an option on some aeroplanes or as supplemental type certificates (STCs). Such devices provide advisory information only during walk-around inspections. These devices have limited accuracy and reliability. They are, therefore, not intended to accomplish the scheduled tyre pressure maintenance task, but may be used to detect any significant under-inflation.
  — Remote tyre pressure indication systems exist that can be used by maintenance personnel and also by pilots of business jets to check tyre pressures on the ground. Sensors are installed on the wheels and communicate via wireless signals to a handheld electronic device that indicates the pressure of each tyre.
  — Other more advanced technologies are being developed by industry with the objective of being able to simultaneously and remotely indicate all the tyre pressures of an aircraft on a handheld device (e.g. electronic tablet or smartphone).
(l) SAE ARP 6152 'Aircraft Tires Service Overload Capability' was issued in 2013. It recommends that tyres should be designed with a double-load cycle capability. This assumes that one tyre fails before taxiing, and, therefore, the companion tyre

must be able to carry the increased load for one complete flight cycle (taxi-out, take-off and landing).

(m) SAE ARP 5265 'Minimum Operational and Maintenance Responsibilities for Aircraft Tire Usage' was issued in 1990, and then revised in 2014 (rev. B). It provides criteria for the installation, inflation, inspection, and maintenance of aircraft tires. The standard recommends a daily pressure check using a calibrated gauge; deferring pressure checks to multiple day intervals is not recommended and is not considered to be in line with best industry practices.

(2) Regulators

(a) The FAA has issued two safety alerts for operators (SAFOs) stressing the importance of ensuring that aircraft tyres are properly inflated, and detailing the potential consequences that incorrect tyre pressures can have on aircraft performance during taxiing, take-off and landing. SAFO 09012 was issued on 12 June 2009, and SAFO 11001 was issued on 6 January 2011. SAFO 11001 was then endorsed by EASA through Safety Information Bulletin (SIB) No 2013-10 issued on 10 July 2013.

(b) FAA Advisory Circular (AC) 20-97B, dated 18 April 2005, provides guidance to operators to perform a tyre pressure check daily using a calibrated gauge whose scale is suited to the pressure range that is being monitored.

(c) FAA AC 145-4A, dated 10 July 2006, provides guidance for the development, qualification, and approval of bias (i.e. cross-ply) and radial aircraft tyre retreads, their repair and process specifications, and the use of special non-destructive inspection (NDI) techniques. This AC states that '*the long term integrity and reliability of the retread tire is significantly influenced by the inflation pressure schedule, the frequency of tire pressure checks, and the identification of tire removal conditions that may impact the continued airworthiness of the tire*.'

Even with these actions, evidence from aircraft in-service (reported occurrences) shows that some large aeroplanes continue to operate with mis-serviced tyres.

ii) Actions taken to improve tyre and wheel robustness

Certification rules have evolved over the years and now include the following:

(1) As per CS 25.733(c) (originating from FAA FAR 25.733(c) in 1979 (Amendment 25-49)), if each landing gear axle is fitted with more than one wheel/tyre assembly, a factor of 1.07 is applied to the maximum loads used to certify main landing gear tyres. This would apply to most, if not all, modern CS-25 aeroplane designs.

(2) Both CS 25.731 and CS 25.733 (respectively) require that the wheels and tyres that are fitted to the aeroplane must be approved. The normal accepted means of compliance with this requirement is that the wheel and tyre each receive an (E)TSO approval:

(a) (E)TSO C-135 for the wheel (and brakes, if fitted to the wheel);

(b) (E)TSO C-62 for the tyre.

(3) (E)TSO C-135 requires a roll-on-rim test to be applied to main landing gear wheels. This has increased the robustness of wheel designs to the extent that some wheel

failure cases are no longer considered in aeroplane designs (e.g. wheel rim releases with the landing gear retracted).

(4) (E)TSO C-62 requires the tyre to complete one take-off cycle on a dynamometer at the rated load multiplied by 1.5.

Again, even with these provisions, tyres are still known to fail due to the extreme loads and temperatures associated with operation whilst under-inflated.

iii) Actions taken to improve the protection of aeroplanes against the damaging effects of tyre failures

(1) Regulators

For the certification of large aeroplanes, Amendment 14 of CS-25 introduced a new CS 25.734 specification requiring the safe operation of the aeroplane to be preserved in cases of the damaging effects of tyre debris, tyre burst pressures, flailing tyre strips, and wheel flange debris on systems or structures. AMC 25.734 provides models that define these threats, which can be used to show compliance; these models were developed based on JAA Temporary Guidance Material TGM/25/8. The TGM states that a failure of the axle-companion tyre is not fully mitigated by tyre overload tests. Compliance with this rule mitigates, but may not fully prevent, unsafe conditions from developing from tyre failures. This is reflected in AMC 25.734, paragraph 4(3)(d) which states:

'If the Agency concludes that the applicant has taken all practicable precautions to prevent a Catastrophic failure situation and the probability of the occurrence is consistent with the hazard classification (assuming a probability of companion tyre failure, if applicable, equal to 10 per cent), the design would be considered as compliant with the intent of CS 25.734.'

It should be noted that CS 25.734 assumes the failure of one tyre plus the axle companion. It does not consider the scenario of multiple tyre bursts, on different axles, which can be a consequence of operation with an under-inflated tyre.

Design measures to protection against a threat (e.g. a tyre burst) will always be a compromise due to factors such as space constraints, the location of landing gear articulation, the need to provide power and monitoring to systems on the landing gear, and the need to avoid other risks. Thus, the possibility of an unsafe condition can never be completely eradicated by aeroplane design, and a means to reduce the risk of the tyre failing should be put in place.

(2) Industry

There is an increasing trend for large aeroplanes to be fitted with radial-ply tyres instead of bias ply tyres.

Upon failure, radial tyres tend to shed debris consisting of the tyre tread plus the outermost ply. The items of debris can be large, however, the debris typically departs at a low speed. High-speed debris is also released, but the items of debris are relatively small.

Bias ply tyres can also shed such debris, but they can also shed debris comprising of the tyre tread plus full parts of the carcass, which are stiffer. This debris has the potential to be accelerated and released at high speed.

Therefore it may be possible to consider that failures of radial tyres result in less damage than failures of bias ply tyres.

4.1.2. Safety risk assessment

4.1.2.1 Safety recommendations addressed to EASA and the FAA

Boeing 757-300, registration 4X-BAU, accident at London Gatwick during landing, on 3 October 2000

Both right main landing gear (MLG) aft tyres (No 7 and No 8) failed within a few seconds of each other during landing shortly after the aeroplane touched down. Tyre debris caused damage to various parts of the underside of the right wing (flap, slat, flap track fairings, fuselage/wing fairing), the No 2 engine nacelle and pylon, the right MLG doors and components of the right MLG. In addition, damage was apparent to the hydraulic flexible hoses installed on the right MLG, with two of the six hoses leaking (the No 3 wheel brake line and a bogie tilt actuator line). The forward flexible conduit carrying electrical cables had been struck by tyre debris, but no cable damage was evident.

The investigation concluded that the accident had probably been caused by operating the aeroplane with either tyre 7 or tyre 8 under inflated. It was possible that either or both of the tyres had been damaged prior to this event by being operated while under-inflated or with an under-inflated partner tyre.

No injuries resulted from this accident.

In July 2010, the UK Air Accidents Investigation Branch (AAIB) forwarded Safety Recommendation (SR) UNKG-2002-014 to the European Aviation Safety Agency (EASA):

> **SR UNKG-2002-014:** '*It is recommended that Airworthiness Authorities such as the JAA and FAA consider implementing the measures outlined in AAIB Safety Recommendations 99-11 and 99-12 concerning requirements for tyre pressure monitoring and warning systems*.'

In the course of a previous accident investigation (*BAC 1-11 registration G-AWYR at Birmingham Airport, UK, on 21 November 1997, AAIB Bulletin 4-99, related to a tyre burst during take-off caused by under-inflation*), the following AAIB SRs were raised:

> **SR 99-11:** '*The CAA consider a requirement for the installation, on the wheels of UK registered aircraft where a potentially hazardous level of tyre underinflation can be undetectable by external visual inspection, of a device to provide ready indication of such a condition during routine pre-flight external inspection*.'

> **SR 99-12:** '*The CAA consider requiring the fitment on future aircraft types on the UK Register of a system to provide continuous flight deck indication of tyre pressures and/or warning of abnormal pressures*.'

Mc Donnell Douglas MD-88, serious incident at Vienna Schwechat Airport, on 31 July 2008

The investigation showed that an unsecured valve stem on the rim of tyre 2 worked loose, and the O-ring underneath was torn apart, which had the effect of deflating the tyre. As a result, during the take-off run and past the decision point, the tread of the tyre broke away and struck the aeroplane, breaking off part of the water deflector attached to the left engine. The landing gear well was damaged, and pieces of the tread were thrown into the left engine, which caused a loss of power, and vibration, after which the engine was shut down. As a result of the landing gear well damage, no locking indication of the left-hand landing gear could be observed, and as a precaution, the subsequent landing was performed in accordance with the 'Landing with unsafe landing gear and possible evacuation of the aircraft' checklist. No one was injured during this incident.

In December 2013, the Austrian investigators provided several SRs to EASA/Federal Aviation Administration; the following SR is related to the present RMT:

> **SR AUST-2013-008:** '*EASA, FAA: SE/SUB/ZLF/8/2013: Supplement to Certification Specifications 25*
>
> *(CS-25), pressure displays of landing gear tyres: Insufficient pressure in landing gear tyres can, as happened in this serious incident, cause massive damage to the aircraft and result in flight situations with increased risk. On this topic also see, for example, the accident report issued by the US National Transportation Safety Board (NTSB): Runway Overrun During Rejected Takeoff, Global Exec Aviation, Bombardier Learjet 60, N999LJ, Columbia, South Carolina, September 19, 2008, http://www.ntsb.gov/doclib/reports/2010/aar1002.pdf. CS-25 should be revised to specify installation of pressure indicators for all landing gear tyres in the cockpit of commercial aircraft*.'

Learjet 60, registration N999LJ, accident on 19 September 2008

The aeroplane crashed during a rejected take-off at the Columbia Metropolitan Airport, South Carolina (USA). The accident resulted in four fatalities, including two passengers and both crew members. Two other passengers were seriously injured.

The NTSB investigation revealed that the tyre pressures on the aeroplane involved in the accident had not been checked for approximately three weeks. The tyres of this aeroplane experienced approximately a 2 % loss of pressure per day. The NTSB determined that the tyre pressure at the time of the accident was approximately 140 psi. The recommended tyre pressure is 219 psi.

The under-inflation of the four MLG tyres resulted in the failure of all four MLG tyres. The NTSB found fragments of the failed tyres that revealed the folded rubber and melted nylon that had been used to produce the tyres.

In addition, hydraulic fluid was found on some tyre fragments, confirming that the tyre failure also compromised some elements of the hydraulic system of the aeroplane.

Finally, the NTSB's investigation identified that there was a significant inconsistency in the operating community regarding the pilot's role in ensuring the correct tyre pressures prior to take-off. Visual inspections of high-pressure tyres, such as those of the aeroplane involved in the accident, will not help to detect an incorrectly inflated tyre. By the time a tyre shows visual signs of poor inflation, the tyre manufacturer will require the under-inflated tyre and the axle-mate (the other tyre on the same landing gear) to be replaced.

The NTSB issued several **SRs to the FAA**, including the following:

> '*Require that all 14 Code of Federal Regulations Part 121, 135, and 91 subpart K operators perform tire pressure checks at a frequency that will ensure that the tires remain inflated to within aircraft maintenance manual-specified inflation pressures*.' *(A-10-47)*
>
> '*Require that aircraft maintenance manuals specify, in a readily identifiable and standardized location, required maintenance intervals for tire pressure checks (as applicable to each aircraft)*.' *(A-10-48)*

'Require tire pressure monitoring systems for all transport-category airplanes.' (A-10-50)

4.1.2.2 Review by the SAE A-5 Committee

In 2007, the SAE A-5 Aerospace Landing Gear Systems Committee conducted a review of the damaging effects of tyre and wheel failures, and they issued Aerospace Information Report (AIR) 5699 (issued in November 2007, and reaffirmed on 25 October 2013).

The report provides an analysis of in-service operational data based on databases from the US National Transportation Safety Board (NTSB) over a period of approximately 40 years (from 1966 to 2005) and from major aeroplane manufacturers (time period not indicated).

NTSB data (from occurrences recorded with some level of aeroplane damage) showed that tyre and wheel failure events had resulted in 11 fatal accidents, 8 hull losses with no fatalities, 11 events where debris entered a fuel tank or an engine, 36 events where there was airframe damage, and 7 events where there was a fuselage decompression.

The aeroplane manufacturers' data (the source of which is not substantiated) included a large number of occurrences classified as 'no damage'. It is likely that this represents a better distribution of the hazard severity for an aeroplane fleet, as it does not exclude events in which no damage occurred. The data analysis shows that tyre-pressure-related occurrences represent 65 % of the occurrences. In terms of the severity of the damage, the analysis revealed the following distribution of the classification of occurrences: 8 % substantial, 15 % major, 27 % minor, and 50 % none.

The combination of the available data again indicates that tyre pressure related occurrences are preponderant, representing 65 % of all occurrences. An assessment of the combined data to determine the degree of damage to the aeroplane was not performed due to the differences in scope (NTSB data excludes events with no damage).

Furthermore, the SAE A-5 Committee assessed how potential regulation changes or improved industry practices could mitigate any of the events. The outcome was that the most promising future action (apart from the implementation of tyre servicing with nitrogen) is the implementation of a tyre pressure monitoring system (TPMS). In the view of the SAE International A-5 Aerospace Landing Gear Systems Committee, this could potentially mitigate 38 % of all the events that were reviewed.

4.1.2.3 Review of the EASA occurrences databases

EASA performed a review of the occurrences contained in the EASA occurrences database that are collected through the Internal Occurrence Reporting System (IORS), and in the European Central Repository (ECR) database.

The initial review encompassed the occurrences for which the main causes involved a tyre or wheel failure, and which happened to aeroplanes with MTOWs greater than 2 250 kg during commercial air transport operations (including business/corporate flights) between 2002 and 2016.

A total of 848 occurrences were found, which are classified as follows: 57 accidents, 73 serious incidents and 718 incidents.

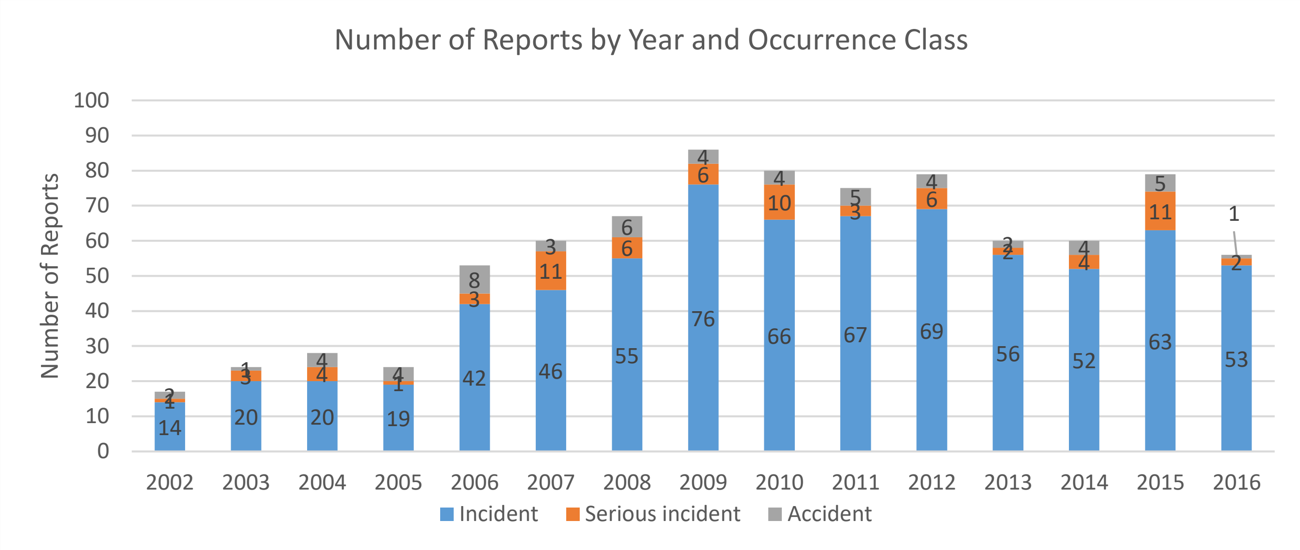


Figure 1: Overall number of reported tyre and wheel failure occurrences per year

The following chart reflects the content of the database. It can be noted that the reports often lack sufficient information to establish the root cause of the tyre or wheel failure; the main category is designated 'tyre burst – unknown cause' (540 occurrences or 64 %):

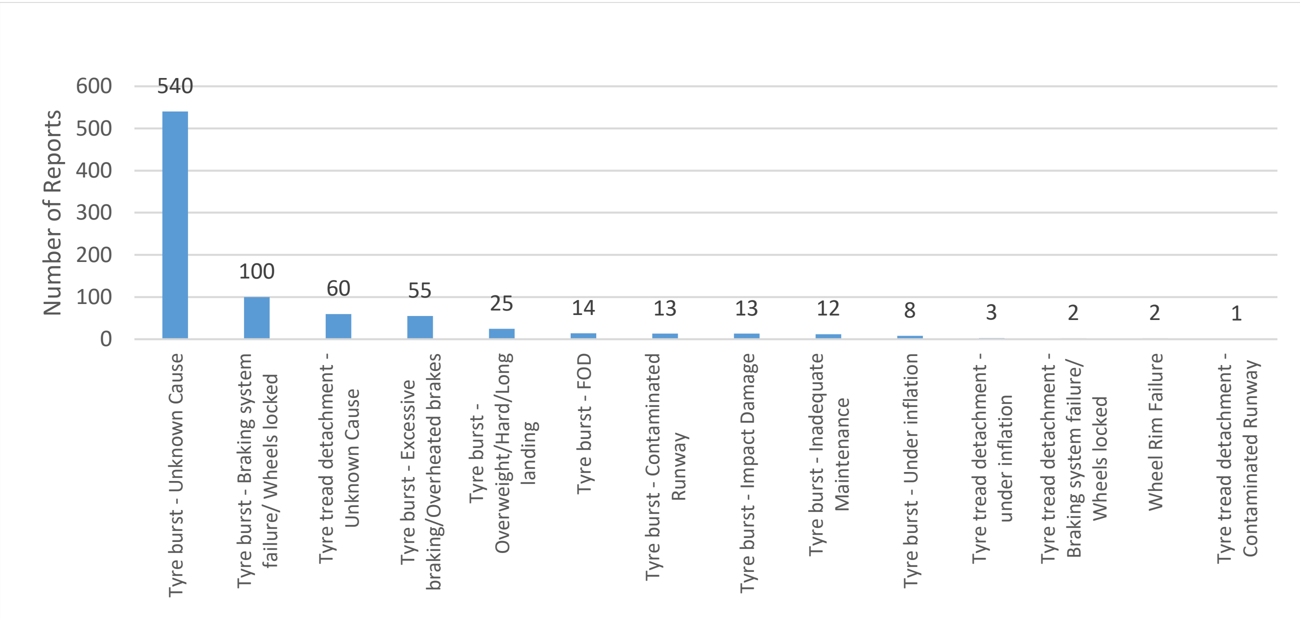


Figure 2: Overview of tyre and wheel failure reports

Based on these findings, a further detailed review was conducted to identify the occurrences concerning 'large aeroplanes' in which inadequate tyre inflation was present or highly probable among the causal factors.

Events in which a tyre blew on the ground during inflation (i.e. maintenance actions) were excluded.

The analysis was focused on the reported serious incidents and accidents (130 occurrences). It was finally determined that there has been 8 occurrences (i.e. 6 % of all occurrences) **between 2002 and 2016**, comprising **2 accidents** (1 fatal (with 4 fatalities and 2 serious injuries) to Learjet 60 registration N999LJ in 2008, and 1 non-fatal with substantial aeroplane damage to Boeing 747 registration VT-AIM in 2005) and **6 serious incidents**. Appendix 1 contains more details and the full list of these occurrences. All these occurrences were related to one or more tyre failure that was linked to tyre under-inflation (7 tyre bursts, 1 tyre tread detachment). The causal factors included: fuse plug leaking (1), incorrect installation of the inflation valve (2), tyre pressure check and inflation not adequate (under inflation) (4), and wheel bolts not adequately torqued (1). In all 8 cases, the tyre(s) failure(s) occurred during take-off.

In addition, at least **3 other accidents are known to have occurred before 2002 that were also caused by inadequate tyre pressures**, including 1 fatal accident:

— DC-8, registration C-GMXQ, on 11 July 1991, crashed after take-off from Jeddah, Saudi Arabia, resulting in 261 fatalities. Cause: under-inflated tyres, two tyres bursts during take-off roll;
— BAC 1-11, registration G-AWYR, on 21 November 1997, tyre burst during rotation for take-off at Birmingham airport, UK. Cause: tyre under-inflation;
— B757-300, registration 4X-BAU, on 3 October 2000, two tyre bursts during landing at London Gatwick airport (UK). Cause: tyre under-inflation.

4.1.2.4 Safety risk portfolio for large aeroplanes

The EASA Annual Safety Review 2018 includes the 'tyre pressure condition' in the list of safety issues in the safety risk portfolio for large aeroplanes (CAT-Airlines and NCC-Business).

The review of high-risk occurrences for large aeroplanes, between 2013 and 2017, did not identify any occurrences triggered by this safety issue. The safety risk portfolio considers 4 priority levels, and this issue is part of priority level 4.The EASA Annual Safety Review 2019 does not include this item in the safety risk portfolio.

4.1.2.5 Data from industry represented in the rulemaking group

The aeroplane and tyre manufacturers that were involved in the rulemaking group were asked to review their databases of tyre and wheel occurrences in order to identify as far as possible the occurrences where inadequate tyre inflation was present among the causal factors.

The data shows differences between the sources in terms of the numbers of occurrences and the root cause analysis. Two sets of data are provided hereafter to illustrate the situation.

<u>Data from one aeroplane manufacturer (one of the largest fleets worldwide)</u>:
The manufacturer reviewed tyre failure reports on all of its aeroplane types **between May 2004 and December 2013**.

Out of 595 occurrences, there were **141 occurrences (23.7 %) related to tyre under-inflation**, 43 occurrences (7.2 %) were caused by foreign object damage (FOD), 64 occurrences (10.8 %) were caused by tyre manufacturing or re-treading defects, however, there were **286 occurrences (48.1 %) with unknown causes**.

Looking at the reasons for the 141 tyre under-inflation cases, it appears that:

— 73 cases (51.8 %) were caused by unknown reasons,
— 26 cases (18.5 %) were caused by a tyre defect which was not detected and not rectified during the retread process,
— 18 cases (12.8 %) were caused by leakage of the wheel (crack, O-ring, tie bolt fracture),
— 11 cases (7.8 %) were caused by a leaking or melted fuse plug,
— 9 cases (6.4 %) were caused by tyre leakage (inner liner or internal separation), and
— 4 cases (2.8 %) were caused by (suspected) incorrect (low) inflation pressures.

<u>Data from one of the tyre manufacturers:</u>

The data encompasses tyre burst occurrences reported for:
— Commercial, regional, general aviation operations;
— Period for injuries and fatalities: ~30 years;
— Period for aeroplane damage: 01/2010 to 10/2017.

Note: incidents involving tyre tread separation are not included. The tyre manufacturer did not review them because of the high number of occurrences (as the analysis would take a lot of time) and because the manufacturer considers that most of the cases are not caused by under-inflation.

Over the last 30 years, 3 occurrences on the ground have been reported where injuries or fatalities occurred during inflation tasks.

Over the last 7 years, there have been 69 tyre bursts that have caused aeroplane damage. The tyres that were involved in these occurrences were 43 % bias ply tyres and 57 % radial tyres.
The statistics gathered confirm that under-inflation was identified in 10 % of the occurrences. In 51 % of the occurrences, the inflation was correct, and in 39 % of the occurrences, the condition of the tyre in terms of its pressure is unknown.

In terms of root causes, in 52 % of the cases, it is unknown, and in 36 % of the cases, FOD is identified as a cause or is probable. Other root causes include operational factors and other issues at the tyre or wheel level.

4.1.2.6 Summary risk assessment

Overall, the data available shows that tyre failure is a relatively common occurrence, whereas wheel failure rarely occurs. In around half of the cases, the available investigation report does not identify the root cause.
Depending on the data source, the proportion of occurrences where inadequate tyre inflation pressure was identified as a causal factor varied between 7 % and 65 %, therefore it is not possible to provide a reliable figure. In terms of inadequate inflation pressure, under-inflation represents the vast majority of the cases. Regarding the reasons for the inadequate inflation, they are multiple, and include both human errors and technical issues leading to leakage or inadequate inflation values.
Between 2002 and 2016, there were at least 2 accidents (including 1 fatal) and 7 serious incidents with the root cause confirmed or highly probable as being inadequate tyre inflation.
The actual figure is most probably higher than that, owing to the lack of data in various reports (unknown root cause). Among these occurrences triggered by a tyre failure (a burst or tread detachment) for an unknown reason (between 2002 and 2016), EASA identified 18 accidents, including 2 fatal accidents. A variety of aeroplane types are represented in this data, however, it can be noted that the 2 fatal accidents occurred with two old types, a Boeing 707 EP-SHE in Tehran-Mehrabad airport (Iran) in 2005 (3 fatalities), and a North American N/A-265 (XA-TFL) in Culiacán (Mexico) in 2007 (9 fatalities).
The case of the Learjet 60, N999LJ, a fatal accident in September 2008, demonstrated the potential threat of multiple and simultaneous tyre failures on several parts of the landing gear, as well as the possible lack of awareness of some personnel about the importance of correct tyre pressure servicing.
Statistics show that the overall number of tyre and wheel failures has not decreased over recent years, with an annual number of failures in the 60-80 range in the EASA occurrences database.
The risk is not the same for all aeroplanes. Aeroplanes that are equipped with on-board integrated tyre pressure monitoring systems (OBTPMSs), which can detect unsafely inflated tyres and alert the crew, are protected against the majority of the scenarios leading to significantly inadequate inflation;

in particular an OBTPMS can prevent inflation errors leading to large-scale under-inflation on multiple tyres, as occurred in the two known fatal accidents. These two fatal accidents could also have been prevented by performing proper tyre pressure servicing at an appropriate interval. Aeroplanes not equipped with OBTPMSs remain exposed to all scenarios, and the safety risk increases with the time interval between pressure checks. The consequences of a tyre or wheel failure are also not the same, depending on the design of the aeroplane. Older designs, which were not certified in accordance with JAA Temporary Guidance Material TGM/25/8, the new CS 25.734 rule (created at Amendment 14 of CS-25), or equivalent standards, are less protected against the damaging effects of tyre and wheel failure. However, even compliance with CS 25.734 does not necessarily provide full protection against the damage caused by a tyre failure.

4.1.3. Who is affected

Large aeroplane manufacturers and their suppliers; operators of large aeroplanes; maintenance organisations.

4.1.4. How could the issue/problem evolve

Various actions that have been implemented to address tyre failures in the past (refer to 4.1.1.3) have improved the safety of large aeroplanes. In the coming years, the proportion of aeroplanes that are compliant with CS 25.734 will increase, and therefore, the number of aeroplanes that are more vulnerable (in terms of the severity and likelihood of damage) as a result of a tyre failure should decrease. However, the risk of an unsafe condition due to operating with mis-serviced or leaking tyre-wheels has not been completely eliminated, and it is not expected to drastically decrease without a regulatory change that mandates additional protective measures.

If no action is taken to better ensure the correct inflation of tyres, the annual number of tyre and wheel failure occurrences may not decrease if the industry does not voluntarily increase the number of aeroplanes that have tyre pressure alerting systems installed, and/or does not take action to better check tyre pressures. With the expected growth of the fleet of large aeroplanes worldwide, this number of occurrences may, on the contrary, increase. Therefore, although the consequences of a tyre or wheel failure are better mitigated on modern designs, the overall number of these occurrences classified as accidents or serious incidents may not come down.

4.2. What we want to achieve — objectives

The specific objective is to decrease the risk of hazardous or catastrophic tyre failures of large aeroplanes caused by inadequate tyre inflation pressure through improvements that will ensure that the tyre inflation pressure remains within the safe levels defined by the aeroplane manufacturer.

4.3. How it could be achieved — options

As indicated by the analysis of occurrences, there is a variety of causal factors that can lead to a tyre being under inflated, and all generations of aeroplanes are susceptible. Such factors include inadequate tyre pressure servicing (too long an interval between checks, an incorrect inflation pressure value being used), and air leakage of the tyre or wheel (caused by human errors, technical failures during maintenance or production, or foreign object damage (FOD)).

Whatever the causal factor involved, the way to detect the problem is to either constantly monitor the tyre pressure, or to perform a tyre pressure check as often as is practicable.

It is believed that a majority of the large aeroplanes in service have their tyre pressures checked daily (e.g. 70 % of the operators who responded to an EASA survey); however, some operational constraints can prevent compliance with daily checks. Therefore, EASA does not envisage universally mandating a daily tyre pressure check for all large aeroplanes.

However, what could be considered is to require aeroplane manufacturers to provide instructions for continued airworthiness (ICA) that include a tyre pressure check task, and to require the tyre pressure check time interval to be substantiated and limited to a maximum value. This would be subject to agreement with EASA. It would also be mandatory for operators to comply with this maximum time interval value.

The above-mentioned occurrences may also have been prevented by the use of a system that could have alerted the crew or provided an indication of an unsafe tyre pressure either before the dispatch of the aeroplane or during the operation of the aeroplane.

Two categories of systems can be envisaged (refer to 4.1.1.3 i)):

— an on-board integrated tyre pressure monitoring system (OBTPMS), or
— a ground tyre pressure indication system (GTPIS).

An OBTPMS has the advantage of constantly monitoring the tyre pressure. It can, therefore, alert the flight crew at any time, except during the flight phases when alerts are inhibited (e.g. during take-off beyond a certain speed). In flight, the system can inform the flight crew of an abnormal tyre pressure so that they can plan the landing with the applicable operational procedures.

A GTPIS provides the possibility to check the tyre pressures at some time before departure. If an under- or over-pressure condition develops after this check has been conducted, then this would not be identified.

Note: In the EU, the use of TPMSs is mandated for the automotive industry by Regulation (EC) No 661/2009 of 13 July 2009 concerning 'type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor'. Refer to Articles 9(2), 13(2) and 13(5). As of 1 November 2012, all new passenger car models (M1) released must be equipped with a TPMS. From 1 November 2014, every new passenger car sold in the European Union must be equipped with a TPMS. In the United States, equivalent legislation has existed since 2005 and has mandated TPMSs on all newly manufactured or imported cars since 2008.

Hence, the following options are evaluated.

Table 1: Selected policy options

Option No	*Short title*	**Description**
0	No policy change	No policy change (no change to the rules; risks remain as outlined in the issue analysis).
1	CS-25 – Tyre Pressure Check Interval	Amend CS-25 to require new applicants to provide in the ICA a tyre pressure check procedure that is scheduled at a suitable time interval (i.e. daily, or at another substantiated interval).
2	CS-25 – Tyre Pressure Check Interval +Part-26/CS-26 – Tyre Pressure Check Interval	Option 1 + amend the Part-26/CS-26 rule to require all existing operators of large aeroplanes to implement in the aeroplane maintenance programme (AMP) a tyre pressure check task at a suitable time interval (i.e. daily, or at another substantiated interval).
3	CS-25 – Alerting System + Part-26/CS-26 – Tyre Pressure Check Interval	Mandate in CS-25 that new applicants install a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.: — either a TPMS, or — a GTPIS. Amend Part-26/CS-26 as described in Option 2.
4	CS-25 – Alerting System + Part-26/CS-26 (newly produced) – Alerting System	Option 3 + amend Part-26/CS-26 to require the installation of a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.: — either a TPMS, or — a GTPIS, on large aeroplanes produced after [*3 years after entry into force of the regulation*].
5	CS-25 – Alerting System + Part-26/CS-26 (full retrofit) – Alerting System	Option 3 + amend Part-26/CS-26 to require the installation of a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.: — either a TPMS, or — a GTPIS, on large aeroplanes after [*3 years after entry into force of the regulation*].

4.4. Methodology and data

4.4.1. Methodology applied

Various techniques are used in order to assess the impact of the different options and to compare them against each other. The comparison of the options is achieved by:

— establishing the criteria to be used for comparing the options (these criteria must be measurable, at least in qualitative terms);
— scoring how well each option meets the criteria (the scoring needs to be relative to the baseline scenario): the results of the scoring originate from various techniques; and
— ranking the options by combining their scores.

The criteria used to compare the options were derived from the Basic Regulation and the guidelines for the RIA. The principal objective of EASA is to '*establish and maintain a high uniform level of civil aviation safety in the Union*', in accordance with Article 1 of the Basic Regulation (Regulation (EU) 2018/1139). Additionally, the Basic Regulation identifies environmental, economic, social, and proportionality objectives.

For the scoring of the impacts, a scale is used to indicate the positive and negative impacts of each option (i.e. from 'very high' to 'very low' negative/positive impacts). The intermediate levels of benefits are termed 'high', 'medium' and 'low', with a 'no impact' score also being possible.

The techniques applied in this IA ranged from cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) to simple multi-criteria analysis. When quantitative information was available, CBA and CEA were applied. They were applied for Options 3, 4 and 5, while for ptions 0, 1 and 2, a purely qualitative assessment was performed.

A CBA quantifies all the impacts in monetary terms, e.g. safety in terms of avoided fatalities and injuries, compliance costs for the industry, environmental costs, etc. The outcome of a cost-benefit analysis is expressed in terms of the net present value or the benefit-to-cost ratio.

A CEA, on the other hand, defines the net cost per prevented fatality, i.e. the cost associated with preventing one fatality. It is most suitable when the assessment has a main fixed goal which is difficult or impossible to monetise, such as the value of preventing a fatality. Both the CBA and CEA techniques also take into account the benefit of avoided aeroplane damage, accident investigation costs, and airport delays and diversions, in order to avoid a result that concentrates only on a single type of benefit. The two techniques were used for the period between 2022 and 2046, i.e. a total of 25 years.

The output from these two techniques feeds the multi-criteria analysis, which compares all the options and their different impacts. Thus, the overall comparison of the options was indeed done in a 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 scenarios to be more easily compared.

4.4.2. Data collection

Various data sources have been used, which are listed below:

— Safety data: as previously presented, a review was conducted of the occurrences present in the EASA occurrences database between 2002 and 2016. These occurrences were collected through the Internal Occurrence Reporting System and from the European Central Repository database, and they concern large aeroplanes for which inadequate tyre inflation is present or is highly probable among the causal factors. This list of relevant occurrences is provided in Appendix 1.

— Two questionnaires were used to collect information, one targeting aeroplane manufacturers, and the other one was aimed specifically for operators. Both questionnaires were distributed among the relevant stakeholder advisory bodies of EASA. By sending out these surveys, data which is not easily available was gathered and used in the development of the cost-benefit, cost-effectiveness and multi-criteria analyses. The two surveys were opened on 12 April 2018, with an initial deadline of 1 June 2018, which was later extended to 17 June 2018.

In total, 10 operators (all from EASA member states) and 4 manufacturers (of which 3 were from EASA member states) responded to the two surveys, respectively. As far as the size of the responding operators is concerned, a variety of fleet sizes was present amongst them, ranging from a total of 3 aeroplanes to 443 aeroplanes in their fleets. Also for the manufacturers, there was a variety in the size of the respondents' organisations.

4.5. What are the impacts

4.5.1. Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA) of mandating the installation of a means to alert the flight crew of an unsafe tyre pressure (OBTPMS or GTPIS)

4.5.1.1 Assumptions

The CBA and CEA of **options 3, 4, and 5** serve as the inputs to the multi-criteria analysis that was used to compare all the options against each other, as contained in the following sub-sections.

Certain assumptions have been made in the aeroplane fleet model that was used in the subsequent analysis. These are listed below:

— there is a linear correlation between the age of the aeroplane and the number of annual flight cycles;
— there is a linear correlation between the age of the aeroplane and the annual flight hours;
— there is average annual growth in the fleet size of 3.4 %;
— a new aeroplane type is launched on average every 5 years; and
— the market share of a new aeroplane type equals 10 %.

The main input parameters for the CBA and CEA can be found below in Table 2, while the other input parameters are defined in Appendix 3.

Table 2 – Main Input Parameters for CBA and CEA

Parameter	Definition	Value		Unit	Source
		OBTPMS	GTPIS		
Development and Certification Cost	All the costs involved in the development and certification of a system, which are accounted for in the first year of the CBA (i.e. 2022)	2,000,000	1,000,000	€	Survey
Proportion of aeroplanes (produced in or before 2018) already equipped	The proportion of aeroplanes which are produced in or before 2018, and are already equipped with the system (OBTPMS or GTPIS).	13		%	Survey (see below)
Proportion of aeroplanes (produced after 2018 with former TC) already equipped	The proportion of aeroplanes which are type certified in 2018 or before, and produced after 2018, and are already equipped with the system (OBTPMS or GTPIS).	40		%	Survey (see below)
Proportion of aeroplanes (produced after 2018 with new TC) already equipped	The proportion of aeroplanes which are type certified and produced in 2019 or later, and are already equipped with the system (OBTPMS or GTPIS).	50		%	Survey (see below)
Cost of installation on newly produced aeroplanes	The total cost involved to install the system on a single newly produced aeroplane.	64,147	6,750	€	Survey
Cost of installation on already produced aeroplanes	The total cost involved to install the system on an already produced single aeroplane.	64,147	6,750	€	Survey
Weight	The additional equipment weight imposed by the system.	20.94	0.525	kg	Survey
Fatal Accident Rate	The frequency at which a fatal accident occurs.	$3.54 * 10^{-9}$		Accidents/flight cycle	ECR and IORS
Non-Fatal Accident Rate	The frequency at which a non-fatal accident occurs.	$2.48 * 10^{-8}$		Accidents/flight cycle	ECR and IORS
Efficiency of the system	The percentage of accidents prevented by the new equipment.	90	60	%	ECR and IORS (see below)
Fatalities per Accident	The proportion of actual fatalities when a fatal accident occurs.	60		%	ECR and IORS
Average Number of Passenger Seats per Aircraft	The average number of passenger seats per aircraft. Used in this cost-benefit and cost-effectiveness analysis as a variable to explore different scenarios.	20 (Low)		-	Based on average number of fatalities
		80 (Medium)			Mid-point between low and high

		140 (High)		Average in EU CS-25 (Flight Global)
Value of a Prevented Fatality	The value corresponding to the prevention of a fatality.	3,500,000	€	European Commission

Since no quantitative information was provided through the survey on the additional maintenance and training costs of the two systems (OBTPMS, GTPIS), despite questions being asked about this, these elements were not analysed in the cost-benefit and cost-effectiveness analysis. Neither is the dispatch reliability cost quantified here, but it should not be forgotten when assessing the results of both analysis.

In addition, the cost of system installation on an already produced aeroplane is assumed to be identical to the cost of installation on a newly produced aeroplane, as shown in Table 2, although there may be some additional cost impact for operators in the first scenario. As a consequence, the scenario where a retrospective installation is mandated (Option 5) is somewhat optimistically evaluated in the cost-benefit and cost-effectiveness analysis, since the retrofit will probably be more costly than an installation on a newly produced aeroplane due to the additional downtime it may cause during the installation work. This should also be kept in mind when interpreting the results.

Furthermore, as can be seen from Table 2, there are three scenarios defined through the parameter 'average number of passenger seats per aeroplane'. By doing so, the effect of different aeroplane sizes can be assessed and the respective sensitivity can be analysed. The values corresponding to these different average number of passenger seats per aeroplane are 20, 80 and 140. The latter is the average of the fleet of EU CS-25 large aeroplanes, while a value of 20 would correspond to the estimated average seating capacity of a business jet. In between those two values, the average of 80 was selected to provide another example and provide these three scenarios.

The efficiency of the two systems (OBTPMS and GTPIS) had to be defined. In order to do so, the options have been assessed against the reported accidents and serious incidents identified in the EASA database 2002-2016 (see Appendix 2), to determine whether they could have prevented these occurrences. It has been assessed that an OBTPMS could have prevented all of the 8 occurrences in the EASA database (2002-2016). It is likely that a GTPIS could have prevented 6 of the occurrences (although in 4 cases there is an uncertainty about how long the aeroplane was operated with under-inflated tyres); in the 2 other occurrences, a GTPIS may have been useful, but there is not enough information to be confident. In order to establish an average percentage value, a scale was defined, with each scale corresponding to a percentage. This scale of the different probabilities of prevention, which was assessed by EASA, is shown in Table 3.

Table 3 – Defined Scaling for Efficiency of Systems

Probability of Prevention of Accident	Scale
Definite	100 %
Highly Probable	90 %
Probable	60 %
Maybe	40 %
No	0 %

Looking at the identified accidents in the ECR and IORS of Appendix 1, the average probability of the prevention of an accident was found to be 90 % for the OBTPMS system, while the GTPIS system resulted in an average efficiency of 60 % in preventing an accident. As a result, these values were used in the cost-benefit and cost-effectiveness analysis.

Finally, the proportion of the aeroplanes in operation that are already equipped with (one of) the two systems required quantification. Since there is no need to install a GTPIS system on an aeroplane that is already equipped with an OBTPMS system, and the installation of an OBTPMS is more widespread on current in-service aeroplanes, the proportion of aeroplanes in operation already equipped with a GTPIS was set equal to the proportion of aeroplanes in operation that are already equipped with an OBTPMS. In order to establish the actual values, as shown in Table 2, the results of the survey were used.

As far as the current in-service aeroplanes are concerned, it was found from the operator survey that 13 % of the total fleet of aeroplanes have an OBTPMS installed. This result is visualised in Figure 3.

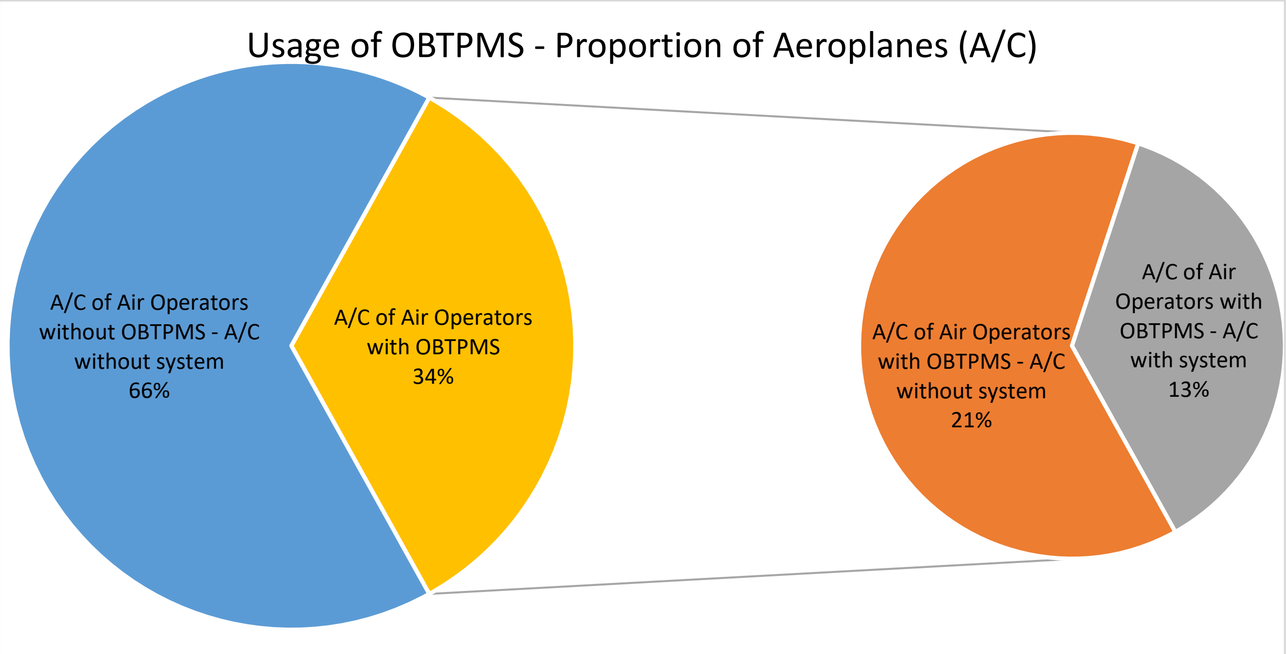


Figure 3 – Usage of OBTPMS as a proportion of the total number of aeroplanes

Regarding the aeroplanes which will be produced in the future that have an existing or a new type certificate, there is a common understanding amongst operators and manufacturers that neither of the two systems will become widely installed throughout the fleet of aeroplanes if the installation is not mandated, as can be seen from Figure 4, Figure 5, Figure 6, and Figure 7. Also, the trend that OBTPMSs will be more widely implemented than GTPISs is confirmed, validating the earlier assumption.

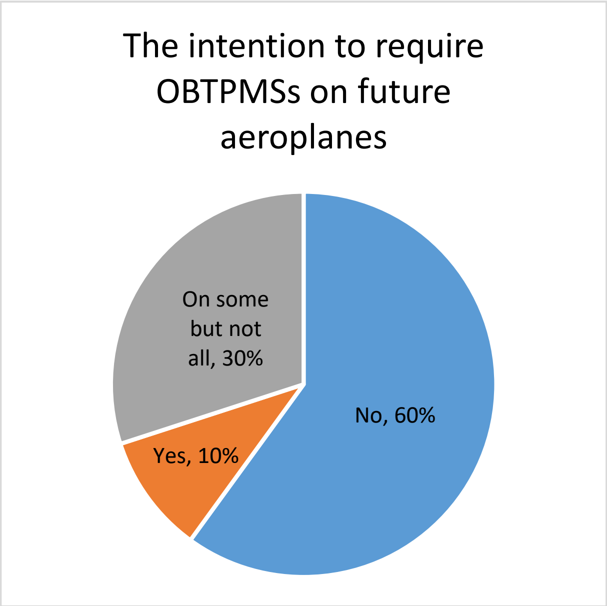


Figure 4 – Requirement for OBTPMS on future aeroplanes

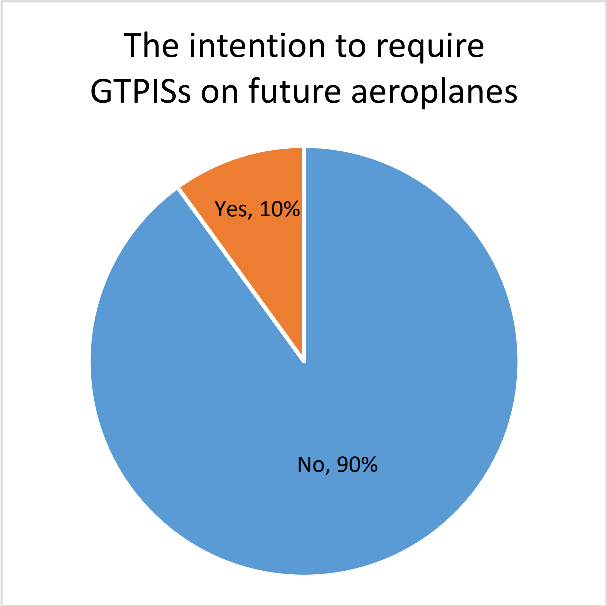


Figure 6 – Requirement for GTPIS on future aeroplanes

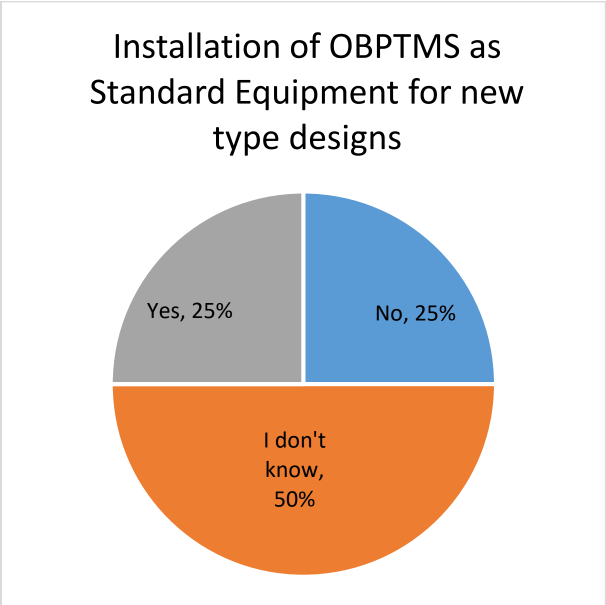


Figure 5- OBTPMS as standard equipment for new type designs

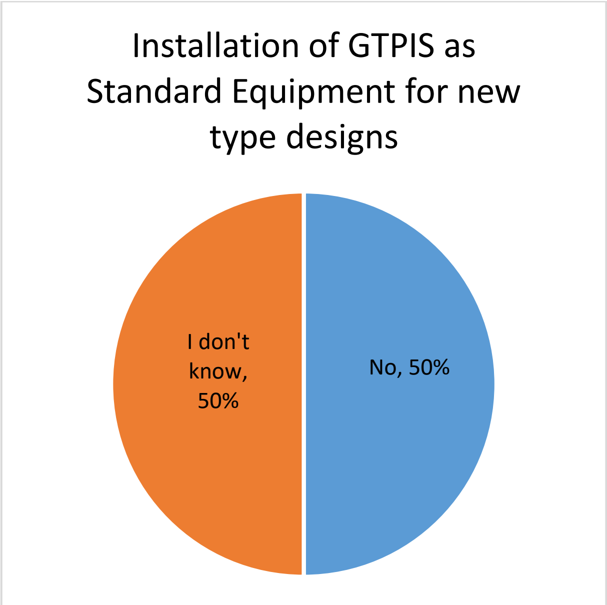


Figure 7 – GTPIS as standard equipment for new type designs

In the manufacturers' survey, an estimate was requested of the proportion of already certified aeroplanes in operation that have one of the two systems installed for aeroplanes that were produced after 2018. Based on this, a value of 40 % was obtained for the proportion of aeroplanes that were produced after 2018 (with a type certificate issued by 2018), which will have installed the OBTPMS system. This value was used in the cost-benefit and cost-effectiveness analysis.

Finally, the proportion of aeroplanes that were produced after 2018 with a type certificate issued after 2018, which will have an OBTPMS installed, was estimated to be 50 %. This was a trade-off between the more increasing trend of installing OBTPMSs on aeroplanes (from 13 % on already-produced aeroplanes to 40 % on newly produced aeroplanes with an existing type certificate), with the reluctance of operators to opt for the installation on future aeroplanes (Figure 4) and manufacturers to install it as standard equipment (Figure 5).

4.5.1.2 Results

Having established an estimate for the proportion of aeroplanes in operation that are equipped with (one of) the two systems, a fleet development model was used to predict the future number of large aeroplanes, along with the flight cycles and flight hours, until the year 2046. The results of this model can be found in Appendix 4. Applying the different options using this fleet development model enables an estimate of the evolution of the fleet of aeroplanes for each of the options to be made. This shows the evolution of the fleet of aeroplanes that are equipped with either an OBTPMS or GTPIS until the year 2046. This evolution for Option 3, 4, and 5 can be found in Figure 8, Figure 9 and Figure 10 respectively.

In these figures and in the proceedings, all aeroplanes are classified according to their status with reference to the baseline year 2018, this being:

— Already produced: aeroplanes already in-service in or before 2018;
— Newly produced (previously issued type certificate): aeroplanes that are produced after 2018 with a type certificate issued by 2018; and
— Newly produced (new type certificate): aeroplanes that are produced after 2018 with a type certificate issued after 2018.

For clarification purposes, the different options are repeated below, to assist with the interpretation of the results.

Table 4: Selected policy options

Option No	*Short title*	**Description**
0	No policy change	No policy change (no change to the rules; risks remain as outlined in the issue analysis).
1	CS-25 – Tyre Pressure Check Interval	Amend CS-25 to require new applicants to provide in the ICA a tyre pressure check procedure that is scheduled at a suitable time interval (i.e. daily, or at another substantiated interval).
2	CS-25 – Tyre Pressure Check Interval +Part-26/CS-26 – Tyre Pressure Check Interval	Option 1 + amend Part-26/CS-26 rule to require all existing operators of large aeroplanes to implement in the aeroplane maintenance programme (AMP) a tyre pressure check task at a suitable time interval (i.e. daily, or at another substantiated interval).
3	CS-25 – Alerting System + Part-26/CS-26 – Tyre Pressure Check Interval	Mandate in CS-25 that new applicants install a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.: — either a TPMS, or — a GTPIS. — Amend Part-26/CS-26 as described in Option 2.
4	CS-25 – Alerting System + Part-26/CS-26 (newly produced) – Alerting System	Option 3 + amend Part-26/CS-26 to require the installation of a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.:

		— either a TPMS, or — a GTPIS, on large aeroplanes produced after [*3 years after entry into force of the regulation*].
5	CS-25 – Alerting System + Part-26/CS-26 (full retrofit) – Alerting System	Option 3 + amend Part-26/CS-26 to require the installation of a means to alert the flight crew of an unsafe tyre pressure either before dispatch of the aeroplane, or during the operation of the aeroplane, i.e.: — either a TPMS, or — a GTPIS, on large aeroplanes after [*3 years after entry into force of the regulation*].

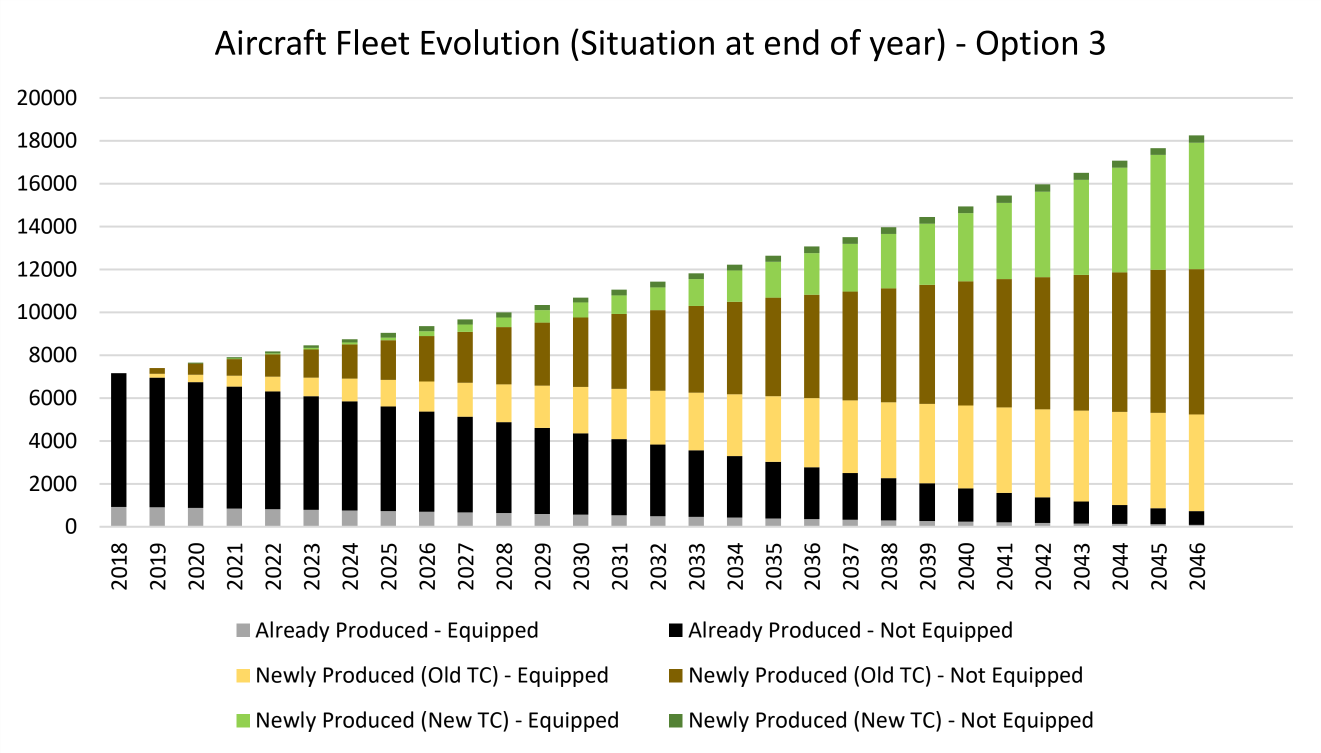


Figure 8 – Aeroplane Fleet Evolution for Option 3 (Equipped = either OBTPMS or GTPIS)

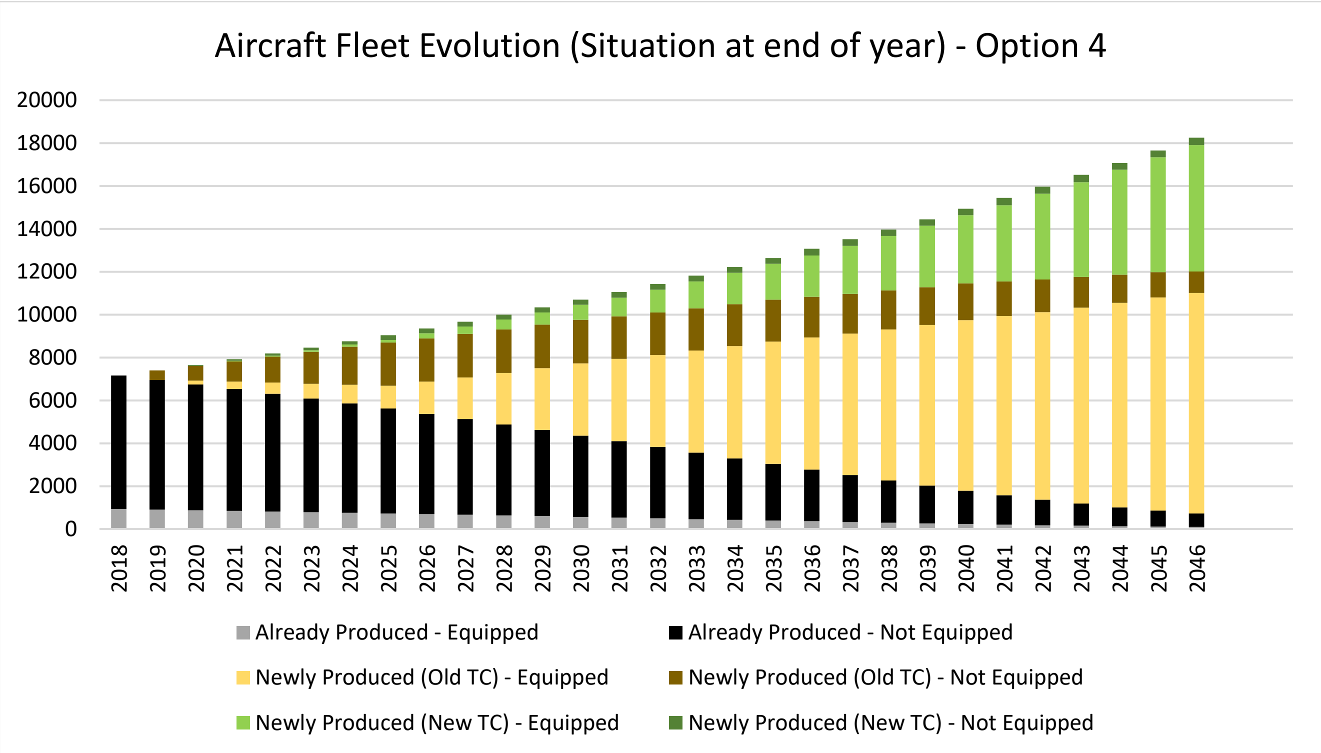


Figure 9 – Aeroplane Fleet Evolution for Option 4 (Equipped = either OBTPMS or GTPIS)

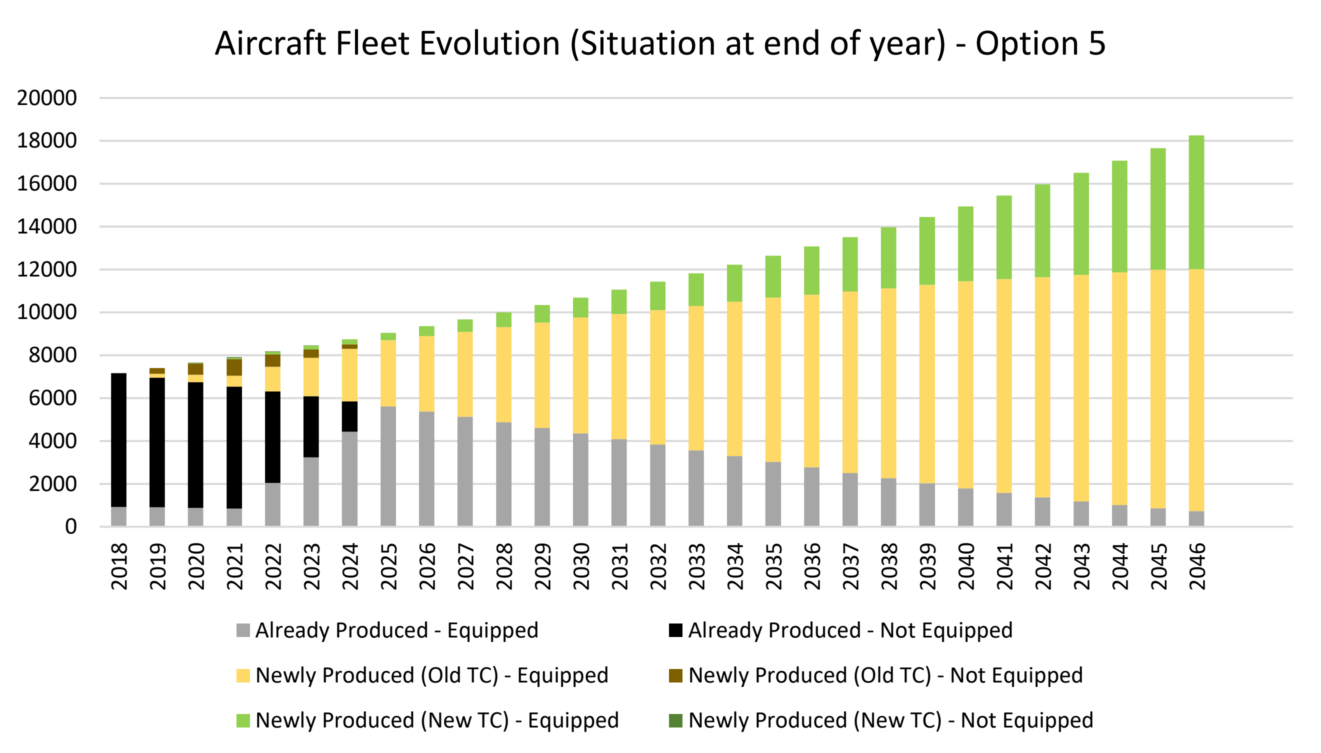


Figure 10 – Aeroplane Fleet Evolution for Option 5 (Equipped = either OBTPMS or GTPIS)

With this information, the cost-benefit and cost-effectiveness analysis can be conducted. For this particular case, the following costs and benefits were modelled:

- Development and certification costs;
- Retrofit and installation costs;
- Additional fuel and CO2 costs;
- The benefit of prevented fatalities;
- The benefit of avoided accident investigations;
- The benefit of avoided aeroplane damage; and
- The benefit of avoided airport disruption.

All these costs and benefits lead to the following output, on which an assessment to compare the different options can be conducted:

- CBA ratio: the total benefits divided by the total cost: a value higher than 1 indicates a cost-efficient strategy, as the benefits would be greater than the costs.
- Net present value: the total benefits minus the total cost: a positive value indicates a strategy where the benefits are greater than the cost. The values have been discounted in order to calculate the present value.
- Discounted prevented fatalities: the total number of prevented fatalities, but discounted to account for a time preference for the present, a technique which was also employed for the economic parameters. The mathematical formula for discounting a given value Y by a discount rate X can be found below

$$Y_{discounted} = \frac{Y_{non-discounted}}{(1+X)^{Year\ -\ Year_{baseline}}}$$

- Net cost per prevented fatality: the net present value, excluding the prevented fatalities, divided by the discounted prevented fatalities, it indicates the net cost to avoid one single fatality.

Table 5 shows all these output parameters for the three options (Option 3, 4, and 5) in combination with the variation in the average number of passenger seats per aeroplane for the two systems (OBTPMS and GTPIS). The breakdown of the total costs and benefits can be retrieved in Appendix 5 and Appendix 6.

Table 5 – Results of Cost-Benefit and Cost-Effectiveness Analysis for Options 3, 4 and 5 with variable number of pax. seats

		Average Number of Pax Seats = 20			Average Number of Pax Seats = 80			Average Number of Pax Seats = 140		
		Option 3	Option 4	Option 5	Option 3	Option 4	Option 5	Option 3	Option 4	Option 5
CBA Ratio [-]	GTPIS	0.301	0.373	0.413	0.567	0.702	0.779	0.833	1.032	1.144
	OBTPMS	0.045	0.052	0.057	0.085	0.098	0.107	0.125	0.145	0.157
Net Present Value [M€]	GTPIS	-8.349	-21.880	-43.754	-5.174	-10.382	-16.498	-1.999	1.117	10.759
	OBTPMS	-114.360	-353.959	-766.619	-109.597	-336.710	-725.734	-104.835	-319.462	-684.850
Discounted Prevented Fatalities [-]	GTPIS	0.40	1.44	3.40	1.30	4.72	11.19	2.21	8.01	18.98
	OBTPMS	0.59	2.15	5.10	1.96	7.08	16.78	3.32	12.01	28.47
Net Cost per Prevented Fatality [M€]	GTPIS	24.568	18.745	16.361	7.470	5.699	4.974	4.404	3.360	2.933
	OBTPMS	195.884	167.915	153.728	59.555	51.052	46.739	35.116	30.102	27.559

As can be seen from Table 5, there are only two cases (grey highlights) where a cost-efficient scenario is present, i.e.:

— in the case of a GTPIS implementation following Option 4; and
— in the case of a GTPIS implementation following Option 5.

For all three of the defined average numbers of passenger seats per aeroplane, Option 5 consistently scores slightly higher, but close to the Option 4 result. Taking into account the fact that the cost of a retrofit exercise has been set as being the same as the cost of installation on a newly produced aeroplane, which is a likely underestimate of the actual cost, it can be deduced that in reality, the full retrofit scenario (Option 5) will be less desirable than the scenario where only newly produced aeroplanes are targeted (Option 4), when comparing the two options from a cost-benefit and cost-effectiveness point of view. Obviously, due to the higher efficiency of the OBTPMS compared with the GTPIS, the OBTPMS prevents more fatalities, albeit at an additional cost. It should be noted that none of the options specifies which of the two systems would need to be installed.

Figure 11 visualises the trend of the CBA ratio with the average number of passenger seats for the two systems and the three options.

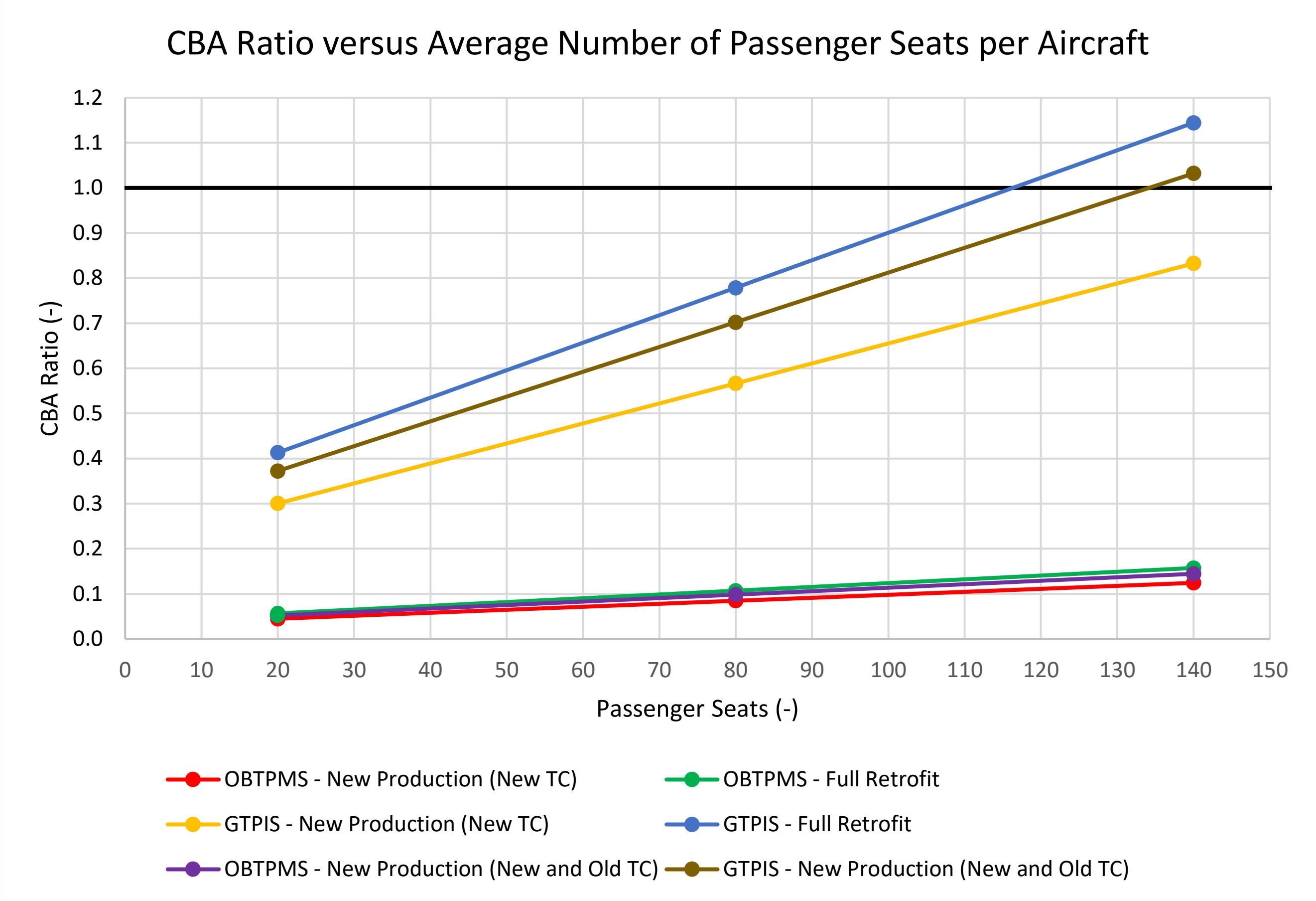


Figure 11 – Variation of CBA Ratio with the average number of passenger seats per aeroplane (OBTPMS and GTPIS)

Similarly as with Table 5, it is also visible from Figure 9 that only two cases score positively from a cost-benefit perspective, these being Option 4 and Option 5, applying GTPISs for an average number of passenger seats per aeroplane equal to 140.

Also, the sensitivity of the cost-benefit ratio to the average number of passenger seats per aeroplane can be assessed from Figure 11. It is clear that all the options related to the GTPIS are more sensitive to the average number of passenger seats, compared with the OBTPMS options. Furthermore, Figure 9 shows that requiring the installation of an OBTPMS, independent of which option is pursued and how high the average number of passenger seats per aeroplane is chosen, will never reach a point at which the benefits outweigh the costs.

The economics of the two cases, i.e. GTPIS combined with an average 140 passenger seats and Options 4 and 5, are broken down in Figure 12 and Figure 13. Here, the total annual cost, benefit and cumulative net cost/benefit are depicted for each year.

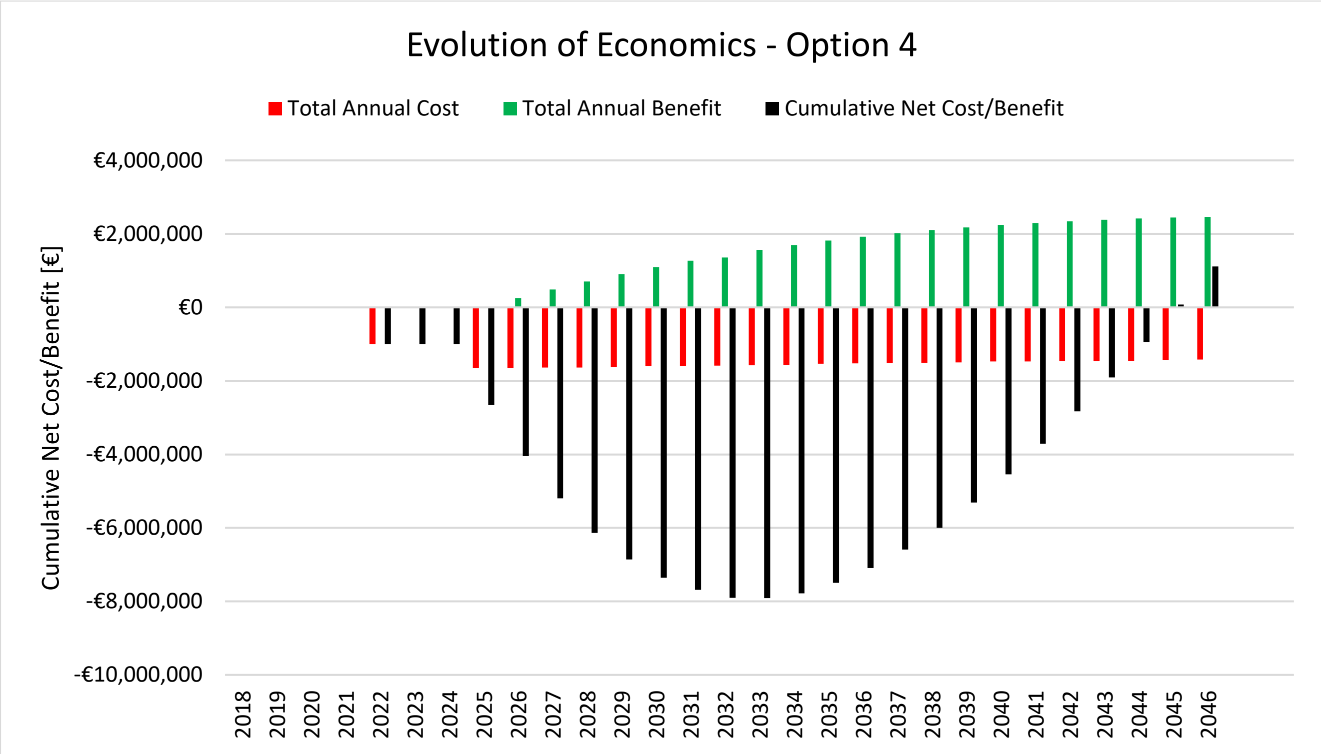


Figure 12 – Evolution of Economics of Option 4 (GTPIS) with an average number of passenger seats per aeroplane of 140

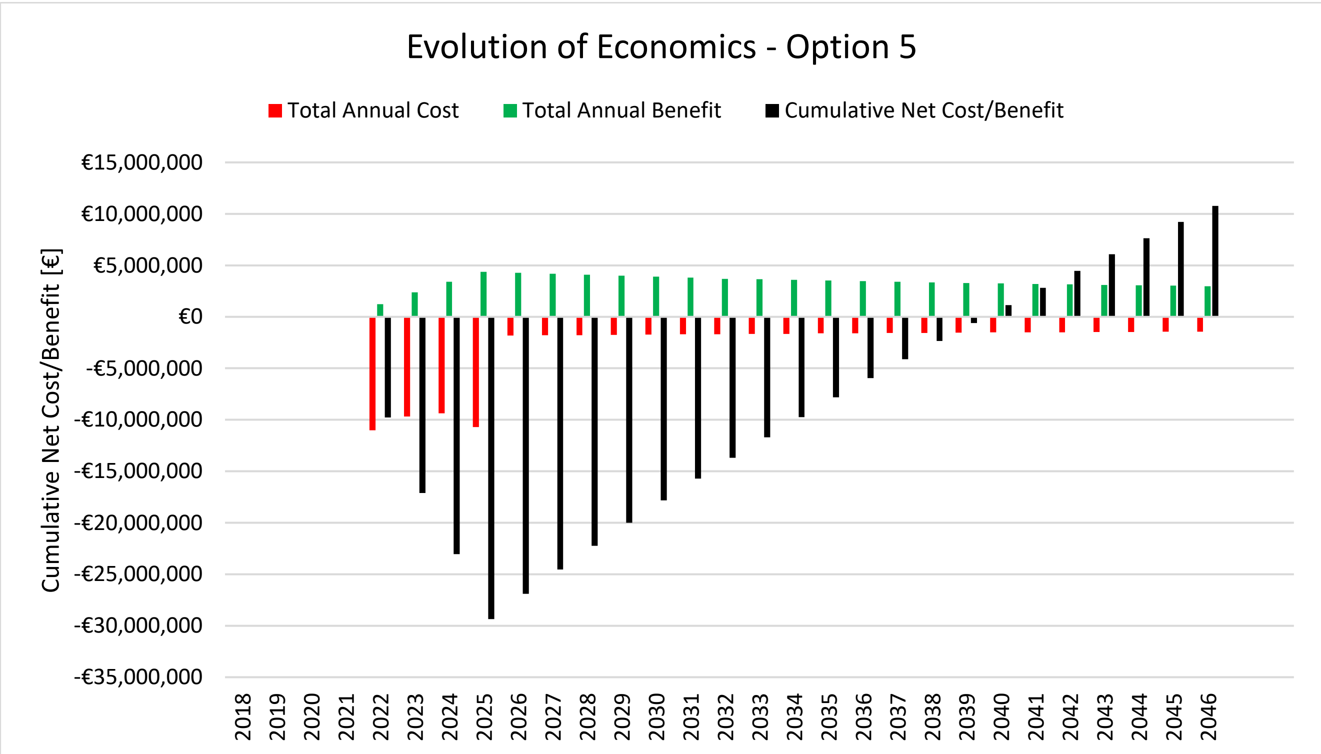


Figure 13 - Evolution of Economics of Option 5 (GTPIS) with an average number of passenger seats per aeroplane of 140

From these figures, it can be seen that a break-even point is reached for Option 4 in 2045, which Option 5 would have already reached in 2040O. Nevertheless, the fact remains that Option 5 was optimistically assessed due to the value selected for the cost of retrofit, which has been taken to be equal to the cost of installation on a newly produced aeroplane.

In conclusion, the cost-benefit and cost-effectiveness analyses indicate that only one scenario, i.e. equipping aeroplanes with a GTPIS and an average number of passenger seats per aeroplane of 140 (or more), will provide a situation where the benefits are greater than the cost, if a full retrofit or a production cut-in is performed. The results of these cost-benefit and cost-effectiveness analysis will be used in the later subsections, where other impacts are analysed to compare the options.
Proposal to stakeholders on economic impacts:

Stakeholders are invited to provide quantified justification elements on the possible economic impacts of the options proposed, or alternatively to propose another justified solution to the issue.

4.5.2. Safety impact

Regarding Option 0, since no policy action would be taken, no fatalities or accidents will be prevented. As a direct quantification of the number of fatalities prevented by Option 1 and Option 2 (requiring a daily pressure check to be used, or a check at another interval agreed with EASA or the competent authorities of Member States) is rather difficult to estimate, the occurrences found in the ECR and IORS database between 2002 and 2016 have been reviewed. Among the 8 occurrences (accidents and serious incidents triggered by inadequate tyre inflation pressure), a daily tyre pressure check would probably have prevented 2 occurrences, in 1 case it would not have helped, and in the other 5 cases, it may have prevented the occurrence depending on the duration of the under-inflation or the leakage rate. The benefit of a greater pressure check time interval, limited to a reasonable value agreed with EASA, is difficult to assess: in 1 case, it would have prevented the accident, in 1 case, it would not have helped, and in the other 6 cases, it may have prevented the occurrence depending on the value of this interval and other factors.
One of the outputs of the cost-benefit analysis is the number of prevented fatalities of Options 3, 4, and 5 between 2022 and 2046, both discounted and non-discounted. Table 5 displays the discounted values for the different scenarios, while Figure 12 shows the variation of the non-discounted prevented fatalities with the average number of passenger seats per aeroplane.

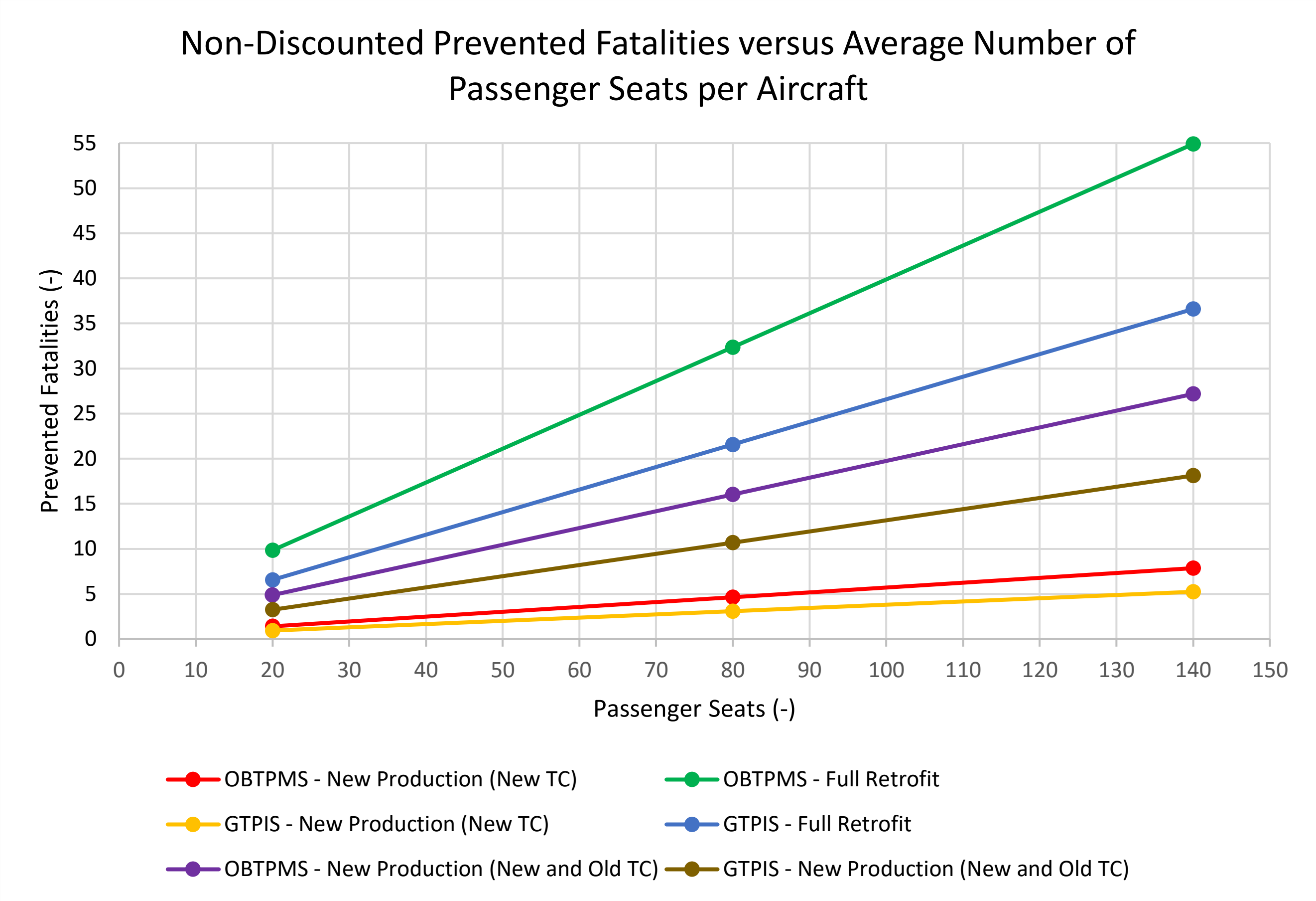


Figure 14 – Variation in the non-discounted prevented fatalities versus the average number of passenger seats per aeroplane

As can be seen from Table 5 and Figure 14, the full retrofit scenario (Option 5) achieves the greatest number of prevented fatalities, followed by targeting all newly produced aeroplanes (Option 4). Mandating the installation of a system only on newly certified aeroplanes (Option 3) prevents the smallest number of fatalities. For each of these options, the OBTPMS prevents more fatalities than the GTPIS due to its higher efficiency.

Combining all the previous information, the following scoring of the different options for the safety impact is proposed:

Option 1: 0 to +

Option 2: +

Option 3: + to ++

Option 4: ++

Option 5: ++ to +++

4.5.3. Environmental impact

Regarding Option 0, since no policy action would be taken, no environmental impact can be avoided or caused.

Regarding the daily tyre pressure check, there is no impact on the environment through additional fuel or CO_2, as no system is added to the aeroplane.

Through the use of the survey that was directed at the manufacturers, the existence of a significant impact from the two systems (OBTPMS and GTPIS) on the fuel consumption and emissions was checked. Figure 15 and Figure 16 show the replies received regarding OBTPMS and GTPIS, respectively.

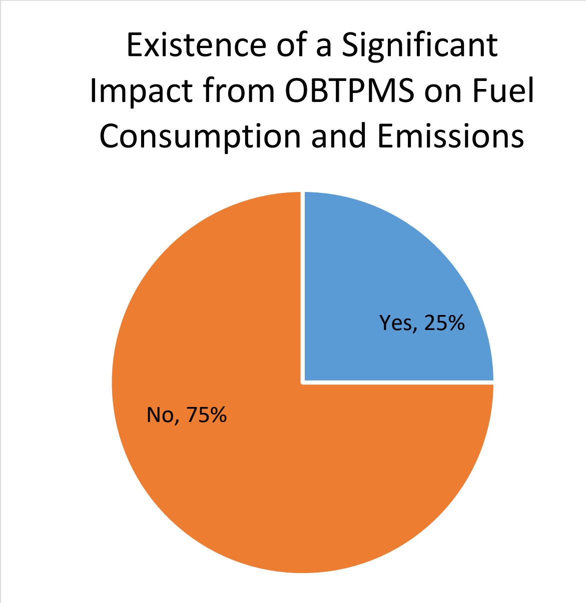


Figure 15 – Existence of a significant impact on fuel consumption and emissions from OBTPMS

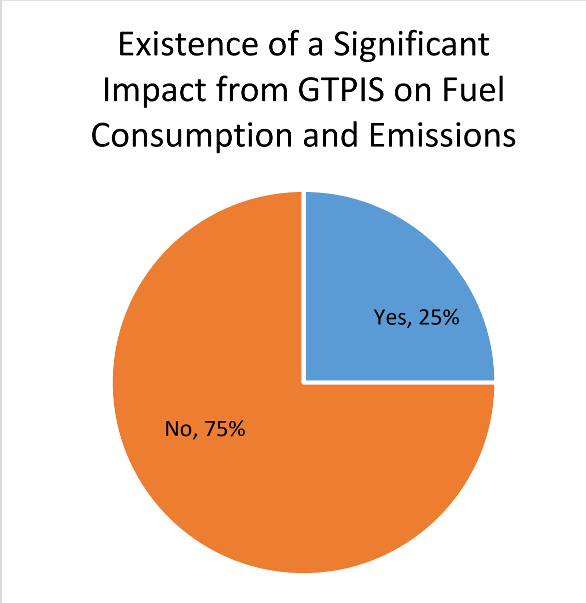


Figure 16 – Existence of a significant impact on fuel consumption and emissions from GTPIS

The majority of the manufacturers believe that adding one of the two systems (OBTPMS and GTPIS) will not cause a significant impact on the fuel consumption or on emissions.
Nevertheless, through the additional weight estimate available from the cost-benefit and cost-effectiveness analysis (see Table 2), the additional fuel and CO_2 cost was estimated for Options 3, 4, and 5 and the two systems. Since the additional fuel and CO_2 caused by the addition of a system is independent of the average number of passenger seats per aeroplane, only one value is obtained for these parameters per option for each of the two systems.
Table 6 provides the values for the discounted additional fuel and CO_2 costs between 2022 and 2046 for Options 3, 4, and 5, and for each of the two systems.

Table 6 – Discounted Additional Fuel and CO2 Costs for Options 3, 4 and 5

Discounted Cost	System	Option 3	Option 4	Option 5
Additional Fuel Cost [M€]	GTPIS	0.362	1.309	3.021
	OBTPMS	14.451	52.229	120.531
Additional CO2 Cost [M€]	GTPIS	0.092	0.322	0.660
	OBTPMS	3.680	12.830	26.329

As shown by Table 6Table , an additional fuel and CO_2 cost is to be expected due to the additional weight of the aeroplane. Between the two systems, the OBTPMS incurs higher negative impacts due to it being a more complex and heavy system. For each of these three options, there is the choice between the two systems, giving the user the flexibility to decide which system to install, if one of these three options is pursued. Even though an additional fuel and CO_2 cost is apparent from the cost-benefit and cost-effectiveness analysis for Options 3, 4, and 5, the proportion it represents compared with the total cost is still relatively low, as can be seen from Appendices 5 and 6.

Combining all the previous information, the following scoring of the different options for the environmental impact is proposed:

Option 0: 0

Option 1: 0

Option 2: 0

Option 3: - to 0

Option 4: -

Option 5: -- to -

4.5.4. Social impact

Regarding Option 0, since no policy action would be taken, no social impact is expected.

As far as the tyre pressure check conducted daily (or at other interval agreed with EASA or the competent authorities of Member States) is concerned, both small positive and negative impacts are to be expected concerning the social aspect. On one hand, it might create additional labour due to the increased frequency (in some cases) of the tyre pressure check task. On the other hand, a reduction in the interval of the tyre pressure check might not necessarily lead to any additional workload. This is because a tyre pressure check can be conducted in parallel with other tasks which already need to be performed on an aeroplane (e.g. visual checks of the tyre condition).

Introducing a new system onto an aeroplane (either a GTPIS or OBTPMS for Options 3, 4, and 5) will result in the need for additional training for flight crew and maintenance personnel, both initial and recurrent. Nevertheless, this impact is estimated to be rather low, which is also consistent with the results from the survey of manufacturers.

Combining all the previous information, the following scoring of the different options for the social impact is proposed:

Option 0: 0

Option 1: -/+

Option 2: -/+

Option 3: 0

Option 4: 0

Option 5: 0

4.5.5. Economic impact

In order to assess the economic impact of applying a daily tyre pressure check, the operator survey results were consulted. Figure 17 displays the current time interval strategy between tyre pressure checks of the operators, expressed in the maximum elapsed time in hours.

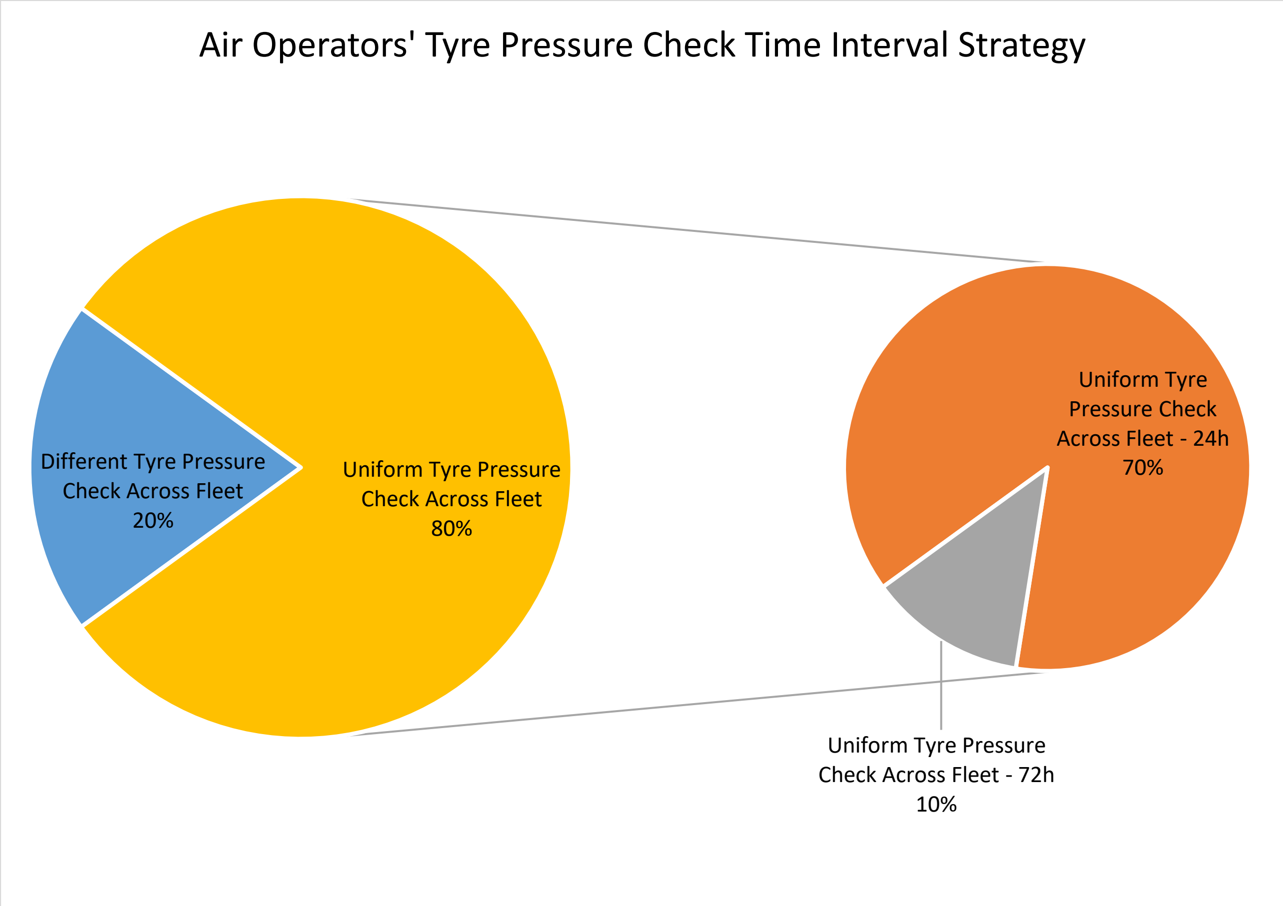


Figure 17 – The time interval between tyre pressure checks, expressed in the maximum elapsed time in hours, of operators

In order to also incorporate the size of the different operators, the proportion of aeroplanes that would be impacted by the application of a mandatory daily tyre pressure check is shown in Figure 18.

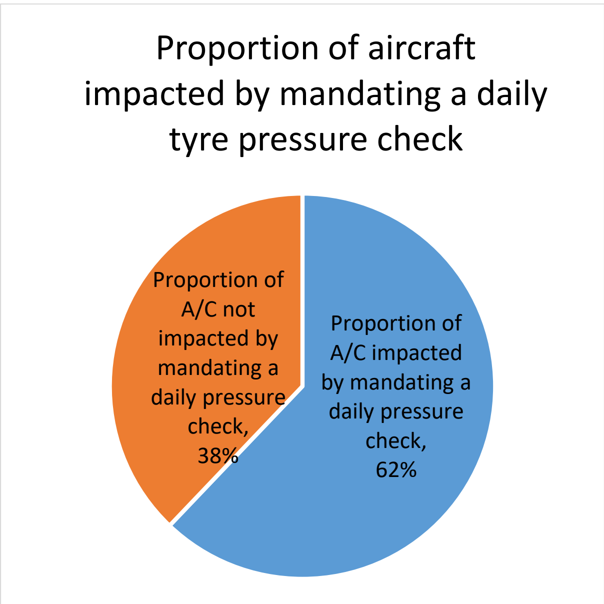


Figure 18 – Proportion of aeroplanes that would be impacted by mandating a daily tyre pressure check

Although most of the operators conduct daily tyre pressure checks on their aeroplane fleets (i.e. 70 %), when looking at the corresponding number of aeroplanes, it appears that the majority of them (62 %) would actually be affected if a daily tyre pressure check was mandated. As a result, there is still a minor economic impact to be expected when a daily tyre pressure check is introduced, albeit less than from the installation of a new system on the aeroplane (OBTPMS or GTPIS).

In order to assess the economic impact of the quantitative options, i.e. Options 3, 4, and 5, the cost-benefit analysis results are used, and more specifically, the total discounted cumulative net cost for the European industry between 2022 and 2046 is derived. This parameter takes into account all the costs (development and certification, installation, additional fuel and CO_2) minus the direct benefits for the industry (aeroplane damage and the avoidance of airport disruption). Table 7 shows this parameter for the three options and two systems, as it is independent of the average number of passenger seats per aeroplane.

Table 7 – Total Discounted Cumulative European Industry Net Cost between 2022 and 2046

		Option 3	Option 4	Option 5
Total Cumulative Industry Net Cost [M€] (excluding economic benefits from prevented fatalities and avoided accident investigation)	GTPIS	10.714	30.459	64.192
	OBTPMS	114.365	354.480	771.937

From Table 7, it is obvious that a substantial difference exists between the two systems, for all options. Comparing the different options, there is a significant increase in the total cumulative industry net cost from Option 3 to Option 4 and from Option 4 to Option 5, due to the increased proportion of aeroplanes which are affected by a mandate to install either an OBTPMS or a GTPIS.

Combining all the previous information, the following scoring of the different options for the economic impact is proposed:

Option 0: 0

Option 1: - to 0

Option 2: - to 0

Option 3: --

Option 4: ---

Option 5: ----

4.5.6. General Aviation and proportionality issues

None identified.

4.6. Conclusion

4.6.1. Comparison of options

Table 8 shows the result of the multi-criteria analysis of the different options, which is derived from the previous subsections.

Table 8 – Multi-criteria analysis comparing the different options

	Option 0 No policy change	Option 1 CS-25 Tyre pressure check interval	Option 2 Option 1 + Part-26/CS-26 Tyre pressure check interval	Option 3 Option 2 + CS-25 Alerting system	Option 4 Option 3 + Part-26/CS-26 Alerting system (Production cut-in)	Option 5 Option 4 + Part-26/CS-26 Alerting system (Full retrofit)
Safety	0	0 to +	+	+ to ++	++	++ to +++
Environmental	0	0	0	- to 0	-	-- to -
Social	0	-/+	-/+	0	0	0
Economic	0	- to 0	- to 0	--	---	----
Overall	0	0	0 to +	- to 0	--	---- to --

When comparing the options in the above table, it worthwhile considering that no root cause was identified for the majority of the occurrences that involved a tyre failure, and therefore the safety benefit shown in the table above may be under-estimated (18 accidents, including 2 fatal, are questionable, as explained in Section 4.1.2.6 above).

Option 0 is neutral, and would leave the identified safety risk at the same level.

Options 4 and 5, although promising the highest safety benefits, are not recommended because of the substantial economic and environmental impacts, which are not sufficiently balanced by the safety benefits.

Option 1 would improve safety in the long term by better controlling the ICA of new aeroplane designs. However, it would not address the risk on existing aeroplanes that are in operation.

Option 2 would improve safety on all aeroplanes in operation, without introducing a significant economic impact, and would have no environmental and social impact. In addition, it is simple to put in place and it does not require design changes to be made.

Option 3 would ensure that future types of large aeroplanes are equipped with an active monitoring system (OBTPMS (probably in most of the cases) or GTPIS) and would therefore further improve safety compared with the maintenance-related action of Option 2. It would better mitigate the risk of human error which still exists in the absence of an active system, and it would create no or very low environmental impact, and no social impact. However, the associated economic impact may be considered disproportionate regarding the magnitude of the safety risk.

Therefore, **Option 2** is selected. With this option, EASA proposes that large aeroplane manufacturers and operators can choose between the tyre pressure check being performed at a suitable interval, and the installation of a tyre pressure monitoring system (as a non-mandatory alternative).

4.7. Monitoring and evaluation

The monitoring of the effects created by the proposed amendment of Part-26 (and the related amendment of CS-26), as well as the corresponding amendment of CS-25, will consist of:

(a) experience gathered by EASA and the competent authorities of Member States regarding the approval of longer tyre pressure check intervals than with a daily check;

(b) the trend in the number of tyre pressure monitoring systems, or other types of alerting systems (e.g. GTPISs) being installed; and

(c) in the long term, the direction of the trend in the numbers of accidents and serious incidents associated with tyre failures, in particular when such failures are caused by the inadequate inflation of tyres.

Item (a) depends on the applications received by EASA and the competent authorities of Member States after the amendment of Part-26/CS-26 and CS-25. A review may be made at the earliest five years after the amendment of Part-26/CS-26 and CS-25.

Item (b) depends on the decision made by large aeroplane manufacturers and operators, as the installation of these systems is not mandated. A review may be made at the earliest five years after the amendment of Part-26 and CS-25.

Item (c) would be available once the aeroplanes operated with tyres checked in compliance with the new Part-26 rule (i.e. either daily, or at another interval approved by EASA or the competent authorities of Member States) have experienced sufficient time in operation. In order to obtain relevant statistical information, this may be performed at least 5 years after the deadline provided in the new Part-26 rule for compliance of the AMP.

In addition, the changes made to CS-25 and Part-26/CS-26 might be subject to interim/ongoing/ex post evaluation that will show the outcome that is obtained after the application of the new rules, taking into account the earlier predictions made in this impact assessment. The evaluation would provide evidence-based judgement of the extent to which the proposal has been relevant (given the needs and its objectives), effective and efficient, coherent, and has achieved added value for the EU. The decision as to whether an evaluation will be necessary should also be taken based on the monitoring results.

5. Proposed actions to support implementation

— Focused communication for advisory body meeting(s) (TeB, STeB)

(Advisory body members)

N/A

— Providing supporting clarifications in electronic communication tools EASA - NAAs (CIRCABC, SINAPSE or equivalent)

(Primarily targeted audience Competent Authority)

N/

— EASA Circular

(Primarily targeted audience Competent Authority, Industry)

N/A

— Detailed explanation with clarification and indicated hints on the EASA web

(Industry, Competent Authority)

N/A

— Dedicated thematic workshop/session

(Industry, Competent Authority)

N/A

— Series of thematic events organised on the regional principle

(Industry, Competent Authority)

N/A

— Combination of the above selected means

(Industry, Competent Authority)

N/A

6. References

6.1. Affected regulations

— Commission Regulation (EU) 2015/640 of 23 April 2015 on additional airworthiness specifications for a given type of operations and amending Regulation (EU) No 965/2012 (OJ L 106, 24.4.2015, p. 18–22)

6.2. Affected decisions

— ED Decision 2003/002/RM of 17 October 2003 on certification specifications, including airworthiness codes and acceptable means of compliance, for large aeroplanes (CS-25)

— ED Decision 2015/013/R of 8 May 2015 adopting Certification Specifications for additional airworthiness specifications for operations (CS-26 – Issue 1)

6.3. Other reference documents

— European Technical Standard order ETSO-C62e ('Aircraft Tyres'), dated 5 July 2012

— EASA Safety Information Bulletin (SIB) No 2013-10 issued on 10 July 2013 ('Properly Inflated Aircraft Tyres')

— SAE Aerospace Recommended Practice (ARP) 6152 'Aircraft Tires Service Overload Capability' issued on 1 January 2013, reaffirmed on 2 September 2018

— SAE Aerospace Recommended Practice (ARP) 5265 'Minimum Operational and Maintenance Responsibilities for Aircraft Tire Usage' first issued in 1990, revision B reaffirmed on 17 October 2019

— SAE Aerospace Information Report (AIR) 5699, issued November 2007, reaffirmed on 25 October 2013 ('A Guide for the Damaging Effects of Tire and Wheel Failures')

— FAA Safety Alerts for Operators (SAFO) 09012 issued on 12 June 2009 ('Dangers of Improperly Inflated Tires') and SAFO 11001 issued on 6 January 2011 ('The Importance of Properly Inflated Aircraft Tires')

— FAA Advisory Circular (AC) 20-97B, issued on 18 April 2005 ('Aircraft Tire Maintenance and Operational Practices')

— FAA AC 145-4A, issued on 10 July 2006 ('Inspection, Retread, Repair, and Alterations of Aircraft Tires')

— Accident to DC-8, registration C-GMXQ, on 11 July 1991, Jeddah, Saudi Arabia

— Accident to BAC 1-11, registration G-AWYR, at Birmingham Airport, UK, on 21 November 1997 (AAIB Bulletin 4-99) - Safety Recommendations 99-11 and 99-12

— Accident to Boeing 757-300, registration 4X-BAU, in London Gatwick, UK, on 3 October 2000 (AAIB Bulletin 7/2002) - Safety Recommendation 2002-014

— Serious incident to Mc Donnell Douglas MD 88, in Vienna Schwechat Airport, Austria, on 31 July 2008 (report reference Mc Donnell Douglas MD 88, serious incident in Vienna Schwechat Airport, on 31 July 2008) – Safety Recommendation SE/SUB/ZLF/8/2013

— Accident to Learjet 60, registration N999LJ, Columbia Metropolitan Airport, South Carolina, USA, on 19 September 2008 – Safety recommendations A-10-47, A-10-48, A-10-50

7. Appendices

7.1. Appendix 1: Occurrences confirmed to be caused by tyre under- or over-inflation - ECR and IORS databases 2002-2016

Occurrence date	Occurrence class per AAIB report	Location name	State of registr	Aircraft registration	Manufacturer/ model	Aircraft Make/ Model	Description	Key Failure Modes	Flight phase of tyre/wheel failure	Comment	Observation	Factors	Fatalities	Serious Injuries	Aircraft damage	Other damage
18 August 2003	Serious incident	Honolulu , Hawaii	Canada	C-FYKX	AIRBUS	AIRBUS-A340	Both of the transport airplane's center landing gear tires (#'s 9 and 10) shredded during takeoff roll, damaging the door retraction arms and multiple fuselage skin panels. The flight crew could not retract the landing gear and elected to return to the departure airport and performed an uneventful	Tyre burst - Under inflation	T/O	Fuse plug had a 6-psi leak over 12 hour period time	The tyre pressure was checked 30 hours before the occurrence	Inadequate Maintenance - Fuse plug leaking	0	0	Damage of the door retraction arms and multiple fuselage skin panels.	
19 December 2005	Accident	Los Angeles , California	India	VT-AIM	BOEING	BOEING-747	On December 19, 2005, at 2030 Pacific standard time, the four right body landing gear (RBLG) tires on a Boeing 747-400, Indian registry VT-AIM, operating as Air India 136, burst during takeoff from Los Angeles International Airport, Los Angeles, California. After the event, the airplane circled off shore to jettison fuel in order to land. The specialist that reported and identified the initial debris on runway 25R reported that after the airplane landed there was some debris on runway 25L. As the airplane approached the east end of runway 25L to land, the specialist noted that none of the main body landing gear tires on the right side were evident. The airplane touched down at 2155.	Tyre burst - Under inflation	T/O	Incorrect installation of the inflation valve		Inadequate Maintenance - Incorrect installation of the inflation valve	0	0	Substantial. Wheel well, vertical stiffener, flight control hydraulic pressure line, brake hydraulic line, an electrical control unit, puncture in the upper pressure deck, one light, puncture on fwd body landing gear door, main body landing gear door, link of a door broken, wing to body fairing punctured. The 1580 frame was missing a large piece of the web and lower cap while the upper cap was present but deformed. The 1620 frame had a hole in the web and a cracked upper cap. The fuselage skin underneath the wing-to-body fairing had several punctures adjacent to the fairing damage and several large pieces of the fragmented wheels were found embedded in the skin. The damage to the fuselage under the wing-to-body fairing was located in the area between two lap joints on the lower right side of the fuselage. Between STA 1520 and 1560, there were three relatively large holes, which measured 10 inches by 8 inches, 10 inches by 10 inches, and 8 inches by 4 inches, respectively, along with several smaller holes and scraping damage. There were three additional holes between STA 1600 and 1640 that measured 3 inches by 3 inches, 8 inches by 2 inches, and 10 inches by 16 inches, along with several more areas with dents and scraping damage. The lower fuselage skin aft of the wing-to-body	9 runway lights, 1 taxiway light damaged, runway concrete damage (skid marks, scrape marks, and grooving)
25 November 2007	Serious incident	Phoenix , Arizona	United States	N3744F	BOEING	BOEING-737	On November 25, 2007, at 0042 mountain standard time, a Boeing 737-832, N3744F, registered to and operated by Delta Air Lines, Inc., of Atlanta Georgia, and operating as flight 430, sustained minor damage when the tread on the right outboard tire came off and struck the airplane during takeoff from Phoenix Sky Harbor International Airport (PHX), Phoenix, Arizona. The takeoff was continued and no other anomalies were noted. Soon after leveling off at FL330, the crew was advised by air traffic control that tire fragments had been found on the runway and that they had possibly had a tire failure on takeoff. Shortly thereafter, the crew noticed hydraulic system A was losing fluid. The decision was made for the airplane to divert to Denver International Airport (DEN), Denver, Colorado. After declaring an emergency, the crew made an overweight landing on runway 16R using 40 degrees of flaps. The airplane landed at 0247.	Tyre tread detachment - Under inflation	T/O	The tire was examined by the tyre manufacturer and according to its report, "The most likely cause of the tread separation is [severe] overdeflection [underinflation and/or overloading) during use in service]."		Probably Inadequate maintenance - Tyre pressure check or inflation not adequate (under inflation)	0	0	Hydraulic system A lost fluid. Post-incident inspection revealed the tread on the right outboard tire had come off and had struck the inboard and midspan flaps, necessitating their replacement. In addition, the leading edge of the right horizontal stabilizer had been struck and required replacement.	
23 July 2008	Serious incident	Denver	Canada	C-FYJP	AIRBUS	AIRBUS-A319	On July 23, 2008, approximately 2230 mountain daylight time, an Airbus Industrie A319-114, C-FYJP, registered to and operated by Air Canada and piloted by an airline transport certificated pilot, sustained minor damage when the right inboard tire failed during takeoff at Denver International Airport, Denver, Colorado. According to Air Canada, as the airplane accelerated for takeoff on runway 25, the captain detected a whistling noise and realized his side window was not secured. The takeoff was rejected and the airplane was taxied back. Before the second takeoff was initiated, the crew confirmed that all brake temperatures were below 300 degrees Celsius (C.). Takeoff was initated and gear retraction, which was delayed to allow the brakes to cool as a result of the previous rejected takeoff, was normal. When the flaps were retracted, an F-LOCKED message was received. Slats were retracted and flaps retracted to just short of the number 1 position. An emergency was declared. When the airplane was configured for landing, the following messages were illuminated: RIGHT UNLK ON PANEL; L/G SYS DISAGREE; L/G NOT DOWN. A go-around was executed. The crew then contacted the company's dispatch and maintenance departments. Air Canada's maintenance department informed the crew that if one GREEN triangle on the DOORS page was illuminated, then the right landing gear was effectively down and locked. A flaps 3 landing was made on runway 16R. Although the landing was said to be smooth, there was a noticeable vibration on the right side of the airplane. Minimal braking was used to slow the airplane on the 16,000-foot runway, and there was no difficulty maintaining runway centerline. Post-incident inspection by FAA inspectors and Air Canada personnel revealed the right inboard tire (number 3) had failed.	Tyre burst - Under inflation	T/O	The tyre manufacturer examined the failed tyre and concluded that the tyre sustained a casing break, likely due to prior pressure loss, which led to complete pressure loss, severe stress on the tyre, and the subsequent tread separation.		Probably Inadequate maintenance - Tyre pressure check or inflation not adequate (under inflation)	0	0	Not described in the IORS report, but probably some right side landing gear damages which triggered the ECAM messages (RIGHT UNLK ON PANEL; L/G SYS DISAGREE; L/G NOT DOWN).	

Occurrence date	Occurrence class per AAIB report	Location name	State of registry	Aircraft registration	Manufacturer/ model	Aircraft Make/ Model	Description	Key Failure Modes	Flight phase of tyre/wheel failure	Comment	Observation	Factors	Fatalities	Serious Injuries	Aircraft damage	Other damage
31 July 2008	Serious incident	Vienna International Airport	Spain	EC-FPD	MCDONNELL DOUGLAS	MCDONNELL DOUGLAS-MD88	Iberia McDonnell Douglas MD-88, flight IB3575 from Vienna to Madrid with 122 people on board, suffered a burst tyre, the debris of which was ingested into an engine and caused the failure of that engine, during take-off from Vienna at 1931, local time. When the crew attempted to land back to the airport, the gear was indicated unsafe (not locked into down position). The aircraft over flew the airport twice to have the landing gear checked out by the tower. The crew managed a safe landing at 2050 hrs.	Tyre burst - Under inflation	T/O	Valve stem fastening to rim 2 not secured		Inadequate Maintenance - Incorrect installation of the inflation valve	0	0	Engine damaged by ingestion of tyre debris. Landing gear damage.	
19 September 2008	Accident	Columbia	United States	N999LJ	LEARJET	LEARJET-60	On September 19, 2008, about 2353 eastern daylight time, a Bombardier Learjet Model 60, N999LJ, owned by Inter Travel and Services, Inc., and operated by Global Exec Aviation, overran runway 11 during a rejected takeoff at Columbia Metropolitan Airport, Columbia, South Carolina. The captain, the first officer, and two passengers were killed; two other passengers were seriously injured. The National Transportation Safety Board determines that the probable cause of this accident was the operator's inadequate maintenance of the airplane's tires, which resulted in multiple (four) tire failures during takeoff roll due to severe underinflation, and the captain's execution of a rejected takeoff (RTO) after V1, which was inconsistent with her training and standard operating procedures.	Tyre burst - Under inflation	T/O	All four main landing gear tires on the airplane were operating while severely underinflated during the takeoff roll, which resulted in the tire failures. Tyre pressure had not been checked for approximately 3 weeks.		Inadequate Maintenance - Tyre pressure check and inflation not adequate (under inflation)	4	2	Destroyed by impact forces and the postcrash fire.	Damage to airport property included some of the runway approach lighting, a localizer antenna array, and the airport perimeter fence. Concrete roadway right-of-way markers and a five-lane asphalt road were also damaged.
07 March 2010	Serious incident	Manaus-Eduardo Gomes International Airport, Brazil	Brazil	PT-LJK	LEARJET	LEARJET-35A	During takeoff from runway 10 at Manaus-Eduardo Gomes International Airport, the crew heard a loud external noise followed by a yaw to the right and then new noise, similar to a tire burst. Speed at the time of the occurrence was just below V1. The crew decided to abort the takeoff by reducing the thrust levers and engaging the spoilers. The aircraft did not have reversers and was partially controlled on the center of the runway with use of pedals and differential brakes. However, the aircraft could not be stopped on the runway and overran by about 400 m.	Tyre burst - Tyre under inflation	T/O	Tests conducted on wheels identified that the six connecting bolts of the right outer wheel torque with semicubos were approximately 90% lower than foreseen. It is possible that this fact has contributed to the tire deflation.	Ambulance	Probably Inadequate Maintenance - Wheel bolts not adequately torqued (air leakage)	0	0		
04 May 2010	Serious incident	Incheon International Airport, Republic of Korea	USA	N749SA	BOEING	BOEING-747-300SF	On 4 May 2010 at about 23:21, a Southern Air B747-300SF (Registration N749SA, Freighter, hereinafter referred to as "Flight 720 Freighter") performing flight SO720 from the Incheon International Airport, the Republic of Korea to Anchorage International Airport, the United States, had two tires of the left main body gear disintegrated at a speed of about 150 knots during takeoff rolling, so the captain rejected the takeoff immediately just before the V1 speed.	Tyre burst - Under inflation Note: the official investigation concluded to over pressure/overload	T/O	The number 5 tire ruptured as the tire pressure increased due to the heat originating from the accumulated high temperature and an additional load caused by an imbalance of the diameter between number 5 tire and number 6 tire while the flight 720 freighter was moving a long distance for takeoff, and the number 6 tire ruptured because it could not bear all the load that the number 5 tire had to receive after it had ruptured.	Boeing disagrees with the conclusion of the investigation. Boeing found that the tyre n°5 suffered fatigue effects on the structure from over deflection, which may have been caused by operating with under inflation.	Boeing information: fatigue of the tyre, suspected under inflation, probably maintenance related (inadequate inflation or pressure check). Note: the official investigation refers to operational and maintenance factors: long taxi, difference of tyre diameters (n°5 & 6)	0	0	Left wheel well door was damaged by the collision with the damaged tire fragments, and number 1 hydraulic return line was cut out, and the number 5 and 6 wheels were abraded by friction with the runway. And the thermal Fuses of the wheels were activated so pressure leaked out from 12 tires.	Five (5) taxiway centerline lights were broken.

7.2. Appendix 2: Potential mitigation means for occurrences confirmed to be caused by tyre under- or over-inflation - ECR and IORS databases 2002-2016

Occurrence date	Occurrence class per AAIB report	Location name	State of registry	Aircraft registration	Aircraft Make/ Model	Description	Key Failure Modes	Flight phase of tyre/wheel failure	Factors	On-board integrated tyre pressure monitoring system (OBTPMS)	Ground tyre pressure indication system (GTPIS) (before each flight)	Mandate daily pressure check (e.g. CMR and ALS)	Mandate daily pressure check or other substantiated interval (e.g. CMR and ALS item), with a limit on the interval	Require ICA with daily pressure check or other substantiated interval, with a limit on the interval	Over pressure valve (per CS 25.731(d))	Compliance with CS 25.734 protecting structure & systems against tyre & wheel failure effects (or formerly JAA TGM/25/8)
18 August 2003	Serious incident	Honolulu , Hawaii	Canada	C-FYKX	AIRBUS-A340	Both of the transport airplane's center landing gear tires (#'s 9 and 10) shredded during takeoff roll, damaging the door retraction arms and multiple fuselage skin panels. The flight crew could not retract the landing gear and elected to return to the departure airport and performed an uneventful overweight landing.	Tyre burst - Under inflation	T/O	Inadequate Maintenance - Fuse plug leaking	Yes	Yes	No	No	No	No	No
19 December 2005	Accident	Los Angeles , California	India	VT-AIM	BOEING-747	On December 19, 2005, at 2030 Pacific standard time, the four right body landing gear (RBLG) tires on a Boeing 747-400, Indian registry VT-AIM, operating as Air India 136, burst during takeoff from Los Angeles International Airport, Los Angeles, California. After the event, the airplane circled off shore to jettison fuel in order to land. The specialist that reported and identified the initial debris on runway 25R reported that after the airplane landed there was some debris on runway 25L. As the airplane approached the east end of runway 25L to land, the specialist noted that none of the main body landing gear tires on the right side were evident. The airplane touched down at 2155.	Tyre burst - Under inflation	T/O	Inadequate Maintenance - Incorrect installation of the inflation valve	High probability	Probably Dependent on duration of underinflated operation	Probably Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	No	Maybe. Compliance could have prevented some of the damages on hydraulic and eletrical systems.
25 November 2007	Serious incident	Phoenix , Arizona	United States	N3744F	BOEING-737	On November 25, 2007, at 0042 mountain standard time, a Boeing 737-832, N3744F, registered to and operated by Delta Air Lines, Inc., of Atlanta Georgia, and operating as flight 430, sustained minor damage when the tread on the right outboard tire came off and struck the airplane during takeoff from Phoenix Sky Harbor International Airport (PHX), Phoenix, Arizona. The takeoff was continued and no other anomalies were noted. Soon after leveling off at FL330, the crew was advised by air traffic control that tire fragments had been found on the runway and that they had possibly had a tire failure on takeoff. Shortly thereafter, the crew noticed hydraulic system A was losing fluid. The decision was made for the airplane to divert to Denver International Airport (DEN), Denver, Colorado. After declaring an emergency, the crew made an overweight landing on runway 16R using 40 degrees of flaps. The airplane landed at 0247.	Tyre tread detachment - Under inflation	T/O	Probably Inadequate maintenance - Tyre pressure check or inflation not adequate (under inflation)	High probability	Probably Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	No	Maybe. Compliance should have prevented hydraulic system fluid loss
23 July 2008	Serious incident	Denver	Canada	C-FYJP	AIRBUS-A319	On July 23, 2008, approximately 2230 mountain daylight time, an Airbus Industrie A319-114, C-FYJP, registered to and operated by Air Canada and piloted by an airline transport certificated pilot, sustained minor damage when the right inboard tire failed during takeoff at Denver International Airport, Denver, Colorado. According to Air Canada, as the airplane accelerated for takeoff on runway 25, the captain detected a whistling noise and realized his side window was not secured. The takeoff was rejected and the airplane was taxied back. Before the second takeoff was initiated, the crew confirmed that all brake temperatures were below 300 degrees Celsius (C.). Takeoff was initated and gear retraction, which was delayed to allow the brakes to cool as a result of the previous rejected takeoff, was normal. When the flaps were retracted, an F-LOCKED message was received. Slats were retracted and flaps retracted to just short of the number 1 position. An emergency was declared. When the airplane was configured for landing, the following messages were illuminated: RIGHT UNLK ON PANEL; L/G SYS DISAGREE; L/G NOT DOWN. A go-around was executed. The crew then contacted the company's dispatch and maintenance departments. Air Canada's maintenance department informed the crew that if one GREEN triangle on the DOORS page was illuminated, then the right landing gear was effectively down and locked. A flaps 3 landing was made on runway 16R. Although the landing was said to be smooth, there was a noticeable vibration on the right side of the airplane. Minimal braking was used to slow the airplane on the 16,000-foot runway, and there was no difficulty maintaining runway centerline. Post-incident inspection by FAA inspectors and Air Canada personnel revealed the right inboard tire (number 3) had failed.	Tyre burst - Under inflation	T/O	Probably Inadequate maintenance - Tyre pressure check or inflation not adequate (under inflation)	High probability	Probably Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	No	No

Occurrence date	Occurrence class per AAIB report	Location name	State of registry	Aircraft registration	Aircraft Make/ Model	Description	Key Failure Modes	Flight phase of tyre/wheel failure	Factors	On-board integrated tyre pressure monitoring system (OBTPMS)	Ground tyre pressure indication system (GTPIS) (before each flight)	Mandate daily pressure check (e.g. CMR and ALS)	Mandate daily pressure check or other substantiated interval (e.g. CMR and ALS item), with a limit on the interval	Require ICA with daily pressure check or other substantiated interval, with a limit on the interval	Over pressure valve (per CS 25.731(d))	Compliance with CS 25.734 protecting structure & systems against tyre & wheel failure effects (or formerly JAA TGM/25/8)
31 July 2008	Serious incident	Vienna International Airport	Spain	EC-FPD	MCDONNELL DOUGLAS-MD88	Iberia McDonnell Douglas MD-88, flight IB3575 from Vienna to Madrid with 122 people on board, suffered a burst tyre, the debris of which was ingested into an engine and caused the failure of that engine, during take-off from Vienna at 1931, local time. When the crew attempted to land back to the airport, the gear was indicated unsafe (not locked into down position). The aircraft over flew the airport twice to have the landing gear checked out by the tower. The crew managed a safe landing at 2050 hrs.	Tyre burst - Under inflation	T/O	Inadequate Maintenance - Incorrect installation of the inflation valve	High probability	Probably Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	No	Maybe. Compliance may have mitigated the engine and landing gear damages.
19 September 2008	Accident	Columbia	United States	N999LJ	LEARJET-60	On September 19, 2008, about 2353 eastern daylight time, a Bombardier Learjet Model 60, N999LJ, owned by Inter Travel and Services, Inc., and operated by Global Exec Aviation, overran runway 11 during a rejected takeoff at Columbia Metropolitan Airport, Columbia, South Carolina. The captain, the first officer, and two passengers were killed; two other passengers were seriously injured. The National Transportation Safety Board determines that the probable cause of this accident was the operator's inadequate maintenance of the airplane's tires, which resulted in multiple (four) tire failures during takeoff roll due to severe underinflation, and the captain's execution of a rejected takeoff (RTO) after V1, which was inconsistent with her training and standard operating procedures.	Tyre burst - Under inflation	T/O	Inadequate Maintenance - Tyre pressure check and inflation not adequate (under inflation)	Yes	Yes	Yes	Yes	Yes	No	Maybe. Wheel wells systems protection may have avoided the uncommanded T/R stowage and forward thrust during the rejected T/O ensuing runway excursion.
07 March 2010	Serious incident	Manaus-Eduardo Gomes International Airport, Brazil	Brazil	PT-LJK	LEARJET-35A	During takeoff from runway 10 at Manaus-Eduardo Gomes International Airport, the crew heard a loud external noise followed by a yaw to the right and then new noise, similar to a tire burst. Speed at the time of the occurrence was just below V1. The crew decided to abort the takeoff by reducing the thrust levers and engaging the spoilers. The aircraft did not have reversers and was partially controlled on the center of the runway with use of pedals and differential brakes. However, the aircraft could not be stopped on the runway and overran by about 400 m.	Tyre burst - Tyre under inflation	T/O	Probably Inadequate Maintenance - Wheel bolts not adequately torqued (air leakage)	High probability	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	No	Unknown. Aircraft damage info not available.
04 May 2010	Serious incident	Incheon International Airport, Republic of Korea	USA	N749SA	BOEING-747-300SF	On 4 May 2010 at about 23:21, a Southern Air B747-300SF (Registration N749SA, Freighter, hereinafter referred to as "Flight 720 Freighter") performing flight SO720 from the Incheon International Airport, the Republic of Korea to Anchorage International Airport, the United States, had two tires of the left main body gear disintegrated at a speed of about 150 knots during takeoff rolling, so the captain rejected the takeoff immediately just before the V1 speed.	Tyre burst - Under inflation Note: the official investigation concluded to over pressure/overload	T/O	Boeing information: fatigue of the tyre, suspected under inflation, probably maintenance related (inadequate inflation or pressure check). Note: the official investigation refers to operational and maintenance factors: long taxi, difference of tyre diameters (n°5 & 6)	High probability	Maybe Dependent on duration of underinflated operation	Maybe Dependent on duration of underinflated operation	Maybe	Maybe	No	Maybe. Compliance may have prevented the hydraulic line damage.

7.3. Appendix 3: Other Input Parameters for Cost-Benefit and Cost-Effectiveness Analysis

Parameter	Definition	Value		Unit	Source
		OBTPMS	GTPIS		
Discount Rate	The value by which all the total annual costs and benefits are discounted to take into account the preference for the present over the long-term future.	4.0		%	Standard value in Impact Assessment
Retrofit Deadline Year	The year by which all aeroplanes shall be retrofitted with a sytem installed (TPMS or GTPIS), in the scenario of a full retrofit mandate (Option 5), meaning that all aeroplanes will have to be equipped by the end of the previous year (end of 2025 in this case).	2026 (based upon 31st December 2025)		-	3 years after entry into force of the Part-26 regulation (assumed 2022)
Installation Start Year for newly produced aeroplanes	The year from which newly produced aeroplanes, must be equipped with a system (TPMS or GTPIS) (Option 4).	2026 (corresponding to the 1st of January 2026)		-	3 years after entry into force of the Part-26 regulation (2022)
Installation Start Year for aeroplanes type certificated in compliance with the new CS-25 specifications	The year from which newly produced aeroplanes will be equipped with a system (TPMS or GTPIS), in compliance with their type certification basis which mandates the installation of such system as a result of the amendment of CS-25(Option 3).	2026 (corresponding to the 1st of January 2026)		-	Entry into force of CS-25 amendment (assumed to happen by the end of 2020, with five years additional time for a type certification project)
Fuel Cost	-	1.85		€ / US Gal.	Value as of June 2018
Average Number of Flight and Cabin Crew per A/C	-	5		-	-

Average Load Factor	-	0.805	-	IATA Air Passenger Analysis
Aeroplane Damage per Fatal Accident	The average cost associated with the aeroplane damage after a fatal accident.	16,000,000	€	EASA Research
Aeroplane Damage per Non-Fatal Accident	The average cost associated with the aeroplane damage after a non-fatal accident.	2,600,000	€	EASA Research
Investigation Cost per Fatal Accident	All costs involved during the investigation process of a fatal accident.	10,000,000	€	EASA Research
Investigation Cost per Non-Fatal Accident	All costs involved during the investigation process of a non-fatal accident.	1,000,000	€	EASA Research
Airport Disruption per Fatal Accident	Diversion, cancellation, delay costs.	2,384,500	€	EASA Research
Airport Disruption per Non-Fatal Accident	Diversion, cancellation, delay costs.	2,384,500	€	EASA Research

7.4. Appendix 4: Fleet Development Model used in CBA and CEA

Year	Already Produced			New Production (old TC)			New Production (new TC)			New Deliveries	
	Aeroplanes	Flight Cycles	Flight Hours	Aeroplanes	Flight Cycles	Flight Hours	Aeroplanes	Flight Cycles	Flight Hours	Old TC	New TC
2018	7159	8,968,159	16,689,698	0	0	0	0	0	0	446	0
2019	6956	8,576,699	15,911,778	446	718,714	1,394,981	0	0	0	415	46
2020	6747	8,186,735	15,139,917	861	1,373,152	2,661,524	46	74,230	144,076	428	48
2021	6532	7,798,574	14,374,697	1288	2,036,255	3,941,472	94	149,435	289,664	442	49
2022	6312	7,412,470	13,616,617	1729	2,707,880	5,234,446	143	225,600	436,725	456	51
2023	6085	7,028,668	12,866,181	2183	3,387,969	6,540,230	193	302,723	585,241	470	52
2024	5854	6,647,447	12,123,967	2650	4,076,482	7,858,653	245	380,804	735,201	431	108
2025	5617	6,269,147	11,390,676	3078	4,686,678	9,021,255	353	546,511	1,054,813	444	111
2026	5374	5,894,182	10,667,159	3517	5,304,066	10,194,361	463	714,198	1,377,389	458	114
2027	5127	5,523,020	9,954,398	3968	5,928,631	11,377,868	577	883,893	1,702,956	471	118
2028	4875	5,156,173	9,253,440	4433	6,560,671	12,572,156	694	1,055,096	2,030,524	486	122
2029	4618	4,794,392	8,565,494	4909	7,198,610	13,774,386	814	1,228,725	2,361,857	501	125
2030	4359	4,438,380	7,891,967	5397	7,842,296	14,984,097	938	1,404,171	2,695,746	452	194
2031	4095	4,088,862	7,234,420	5832	8,388,407	16,000,743	1129	1,685,580	3,234,317	465	199
2032	3830	3,746,933	6,594,666	6276	8,938,281	17,021,563	1326	1,648,760	3,153,693	479	205
2033	3564	3,413,786	5,974,838	6729	9,490,902	18,044,656	1528	2,256,981	4,323,494	494	212
2034	3297	3,090,689	5,377,348	7190	10,045,835	19,069,298	1736	2,546,865	4,873,846	509	218
2035	3032	2,779,084	4,804,807	7658	10,602,314	20,094,170	1948	2,839,535	5,428,015	449	300
2036	2770	2,480,509	4,259,896	8057	11,038,888	20,883,772	2241	3,255,522	6,219,936	463	309
2037	2513	2,196,591	3,745,259	8459	11,473,365	21,667,677	2541	3,675,316	7,017,040	477	318
2038	2263	1,928,867	3,263,397	8861	11,904,626	22,444,100	2848	4,098,799	7,819,093	492	328
2039	2022	1,678,650	2,816,484	9263	12,332,381	23,212,937	3162	4,526,348	8,626,846	508	339
2040	1792	1,447,166	2,406,264	9663	12,755,922	23,973,329	3484	4,957,953	9,440,302	437	437
2041	1574	1,235,355	2,033,947	9971	13,034,313	24,452,291	3901	5,534,515	10,532,988	452	452

2042	1371	1,043,870	1,700,156	10273	13,306,308	24,920,436	4327	6,117,341	11,635,047	467	467
2043	1184	872,896	1,404,822	10566	13,572,811	25,380,102	4764	6,707,129	12,747,888	484	484
2044	1013	722,281	1,147,149	10851	13,834,887	25,833,888	5212	7,304,201	13,872,198	501	501
2045	860	591,406	925,599	11126	14,094,333	26,285,711	5670	7,909,038	15,008,984	415	623
2046	724	479,288	737,959	11290	14,186,084	26,415,506	6242	8,688,919	16,483,007	430	645

7.5. Appendix 5: Breakdown of Total Cumulative Discounted Cost and Benefits between 2022 – 2046: OBTPMS

Average Number of Passenger Seats per A/C = 20				
		Option 3	Option 4	Option 5
COST	Development and Certification	€2,000,000	€2,000,000	€2,000,000
	Retrofit and Installation	€99,608,191	€306,385,774	€663,947,229
	Additional Fuel	€14,451,385	€52,228,718	€120,531,001
	Additional CO2	€3,680,460	€12,829,832	€26,328,513
	TOTAL	€119,740,036	€373,444,324	€812,806,743
BENEFIT	Prevented Fatalities	€2,080,528	€7,534,946	€17,860,630
	Accident Investigation Avoided	€798,216	€2,890,862	€6,852,419
	Aeroplane Damage Avoided	€1,605,824	€5,815,733	€13,785,456
	Airport Disruption Avoided	€895,693	€3,243,887	€7,689,221
	TOTAL	€5,380,260	€19,485,428	€46,187,726
	NET PRESENT VALUE	-€114,359,776	-€353,958,897	-€766,619,018
	COST BENEFIT RATIO	0.0449	0.0522	0.0568
	PREVENTED FATALITIES	1.41	4.87	9.84
	DISCOUNTED PREVENTED FATALITIES	0.59	2.15	5.10
	NET COST PER PREVENTED FATALITY	€195,883,512	€167,914,737	€153,727,993

Average Number of Passenger Seats per A/C = 80				
		Option 3	Option 4	Option 5
COST	Development and Certification	€2,000,000	€2,000,000	€2,000,000
	Retrofit and Installation	€99,608,191	€306,385,774	€663,947,229
	Additional Fuel	€14,451,385	€52,228,718	€120,531,001
	Additional CO2	€3,680,460	€12,829,832	€26,328,513
	TOTAL	€119,740,036	€373,444,324	€812,806,743
BENEFIT	Prevented Fatalities	€6,843,062	€24,783,187	€58,745,389
	Accident Investigation Avoided	€798,216	€2,890,862	€6,852,419
	Aeroplane Damage Avoided	€1,605,824	€5,815,733	€13,785,456
	Airport Disruption Avoided	€895,693	€3,243,887	€7,689,221
	TOTAL	€10,142,795	€36,733,669	€87,072,485
	NET PRESENT VALUE	-€109,597,241	-€336,710,656	-€725,734,259
	COST BENEFIT RATIO	0.0847	0.0984	0.1071
	PREVENTED FATALITIES	4.63	16.03	32.37
	DISCOUNTED PREVENTED FATALITIES	1.96	7.08	16.78
	NET COST PER PREVENTED FATALITY	€59,555,362	€51,051,887	€46,738,626

Average Number of Passenger Seats per A/C = 140				
		Option 3	Option 4	Option 5
COST	Development and Certification	€2,000,000	€2,000,000	€2,000,000
	Retrofit and Installation	€99,608,191	€306,385,774	€663,947,229
	Additional Fuel	€14,451,385	€52,228,718	€120,531,001
	Additional CO2	€3,680,460	€12,829,832	€26,328,513
	TOTAL	€119,740,036	€373,444,324	€812,806,743
BENEFIT	Prevented Fatalities	€11,605,597	€42,031,428	€99,630,148
	Accident Investigation Avoided	€798,216	€2,890,862	€6,852,419
	Aeroplane Damage Avoided	€1,605,824	€5,815,733	€13,785,456
	Airport Disruption Avoided	€895,693	€3,243,887	€7,689,221
	TOTAL	€14,905,330	€53,981,910	€127,957,244
	NET PRESENT VALUE	-€104,834,706	-€319,462,415	-€684,849,500
	COST BENEFIT RATIO	0.1245	0.1446	0.1574
	PREVENTED FATALITIES	7.86	27.19	54.90
	DISCOUNTED PREVENTED FATALITIES	3.32	12.01	28.47
	NET COST PER PREVENTED FATALITY	€35,115,906	€30,101,962	€27,558,714

7.6. Appendix 6: Breakdown of Total Cumulative Discounted Cost and Benefits between 2022 – 2046: GTPIS

Average Number of Passenger Seats per A/C = 20				
		Option 3	Option 4	Option 5
COST	Development and Certification	€1,000,000	€1,000,000	€1,000,000
	Retrofit and Installation	€10,481,407	€32,239,859	€69,864,748
	Additional Fuel	€362,256	€1,309,228	€3,021,376
	Additional CO2	€92,259	€321,608	€659,982
	TOTAL	€11,935,922	€34,870,695	€74,546,107
BENEFIT	Prevented Fatalities	€1,387,018	€5,023,297	€11,907,086
	Accident Investigation Avoided	€532,144	€1,927,241	€4,568,280
	Aeroplane Damage Avoided	€1,070,549	€3,877,156	€9,190,304
	Airport Disruption Avoided	€597,128	€2,162,591	€5,126,147
	TOTAL	€3,586,840	€12,990,285	€30,791,817
	NET PRESENT VALUE	-€8,349,082	-€21,880,410	-€43,754,290
	COST BENEFIT RATIO	0.3005	0.3725	0.4131
	PREVENTED FATALITIES	0.94	3.25	6.56
	DISCOUNTED PREVENTED FATALITIES	0.40	1.44	3.40
	NET COST PER PREVENTED FATALITY	€24,568,059	€18,745,253	€16,361,250

Average Number of Passenger Seats per A/C = 80				
		Option 3	Option 4	Option 5
COST	Development and Certification	€1,000,000	€1,000,000	€1,000,000
	Retrofit and Installation	€10,481,407	€32,239,859	€69,864,748
	Additional Fuel	€362,256	€1,309,228	€3,021,376
	Additional CO2	€92,259	€321,608	€659,982
	TOTAL	€11,935,922	€34,870,695	€74,546,107
BENEFIT	Prevented Fatalities	€4,562,042	€16,522,125	€39,163,593
	Accident Investigation Avoided	€532,144	€1,927,241	€4,568,280
	Aeroplane Damage Avoided	€1,070,549	€3,877,156	€9,190,304
	Airport Disruption Avoided	€597,128	€2,162,591	€5,126,147
	TOTAL	€6,761,864	€24,489,113	€58,048,323
	NET PRESENT VALUE	-€5,174,058	-€10,381,583	-€16,497,784
	COST BENEFIT RATIO	0.5665	0.7023	0.7787
	PREVENTED FATALITIES	3.09	10.69	21.58
	DISCOUNTED PREVENTED FATALITIES	1.30	4.72	11.19
	NET COST PER PREVENTED FATALITY	€7,469,539	€5,699,205	€4,974,386

Average Number of Passenger Seats per A/C = 140				
		Option 3	Option 4	Option 5
COST	Development and Certification	€1,000,000	€1,000,000	€1,000,000
	Retrofit and Installation	€10,481,407	€32,239,859	€69,864,748
	Additional Fuel	€362,256	€1,309,228	€3,021,376
	Additional CO2	€92,259	€321,608	€659,982
	TOTAL	€11,935,922	€34,870,695	€74,546,107
BENEFIT	Prevented Fatalities	€7,737,065	€28,020,952	€66,420,099
	Accident Investigation Avoided	€532,144	€1,927,241	€4,568,280
	Aeroplane Damage Avoided	€1,070,549	€3,877,156	€9,190,304
	Airport Disruption Avoided	€597,128	€2,162,591	€5,126,147
	TOTAL	€9,936,887	€35,987,940	€85,304,829
	NET PRESENT VALUE	-€1,999,035	€1,117,245	€10,758,722
	COST BENEFIT RATIO	0.8325	1.0320	1.1443
	PREVENTED FATALITIES	5.24	18.12	36.60
	DISCOUNTED PREVENTED FATALITIES	2.21	8.01	18.98
	NET COST PER PREVENTED FATALITY	€4,404,299	€3,360,449	€2,933,070

8. Quality of the document

If you are not satisfied with the quality of this document, please indicate the areas which you believe could be improved, and provide a short justification/explanation:

— the technical **quality** of the draft proposed rules and/or regulations and/or the draft proposed amendments to them;

— the clarity and readability of the text;

— the quality of the impact assessment (IA);

— application of the 'better regulation' principles[8]; and/or

— others (please specify).

Note: Your replies and/or comments in reply to this section will be considered for internal quality assurance and management purposes only and will not be published in the related CRD.

[8] for guidance see:
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox_en
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how_en)
- https://ec.europa.eu/info/law/law-making-process/planning-and-proposing-law/better-regulation-why-and-how/better-regulation-guidelines-and-toolbox/better-regulation-toolbox_en)