D1.2 – Impact Monitor Toolbox

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Abstract

The present document presents the Impact Monitor Toolbox. This toolbox sets out the requirements and provides practical, hands-on guidance, tips and best practice for the complete cycle of performing impact assessments and monitoring of European R&I in aviation. That is, it is a way of working. Adopting the terminology from EC's Better Regulation, this guidance, these tips and this best practice are denoted by as '*tools*'.

The Impact Monitor Toolbox consists of 26 tools, which cover five main aspects: Assessment- and monitoring-process flow, basics and organisation; Assessment and monitoring specification; Assessment and monitoring set-up; Assessment and monitoring execution; and Assessment and monitoring analysis.

The Impact Monitor Toolbox is a living document and shall be applied, maintained and updated in the follow-up project "Impact Monitor 2".

Keywords

Impact Monitor, Toolbox, impact assessment and monitoring, European R&I in aviation

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Table of Acronyms and Abbreviations

Acronym / Abbreviation	Description / Meaning
ACARE	Advisory Council for Aviation Research and Innovation in Europe
ACI	Airports Council International
ANCAT	Abatement of Nuisances Caused by Air Transport
AQAP	Allied Quality Assurance Publication
ATAG	Air Transport Action Group
ATM	Air Traffic Management
CAA	Civil Aviation Authority
CAEP	Committee on Aviation Environmental Protection
CC-MOD	European Commission's Competence Centre on Modelling
CEAC	Conférence Européenne de l'Aviation Civile (European Civil Aviation Conference)
CERC	Cambridge Environmental Research Consultants
CINEA	European Climate, Infrastructure and Environment Executive Agency
CIRA	Centro Italiano Ricerche Aerospaziali (Italian Aerospace Research Centre)
CLAIM	Clean Aviation Support for Impact Monitoring
CLIMA	Climate Action
ClimOP	Climate Assessment of Innovative Mitigation Strategies towards Operational Improvements in Aviation
DG	Directorate-General
DGCA	Director General of Civil Aviation
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V. (German Aerospace Centre)
DPSIR	Drivers, Pressures, State, Impact and Response
EASA	European Union Aviation Safety Agency
EC	European Commission
ECAC	European Civil Aviation Conference
ECATS	Environmentally Compatible Air Transport System
EEA	European Environment Agency

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ENAC	École Nationale de l'Aviation Civile (National School of Civil Aviation)
ENV	Environment
E-OCVM	European Operational Concept Validation Methodology
EREA	Association of European Research Establishments in Aeronautics
ETS	Emissions Trading System
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
EUROSTAT	Statistical Office of the European Union
FAA	Federal Aviation Administration
FAIR	Findable, Accessible, Interoperable and Reusable
GA	Grant Agreement
GDP	Gross Domestic Product
IATA	International Air Transport Association
ICAO	International Civil Aviation Organisation
IEA	International Energy Agency
ISO	International Organisation for Standardisation
IT	Information Technology
JRC	Joint Research Centre
KPA	Key-performance Area
KPI	Key-performance Indicator
MIDAS	Modelling Inventory and Knowledge Management System of the European Commission
MITG	Modelling and Interdependencies Task Group
MMU	Manchester Metropolitan University
MOVE	Mobility and Transport
NACE	Nomenclature générale des Activités économiques dans les Communautés Européennes (Statistical Classification of Economic Activities in the European Community)
NLR	Stichting Koninklijk Nederlands Lucht- en Ruimtevaartcentrum (Royal Netherlands Aerospace Centre)

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NUTS	Nomenclature des Unités Territoriales Statistiques (Nomenclature of Territorial Units for Statistics)
ONERA	French Aerospace Lab
PJ	Project
PU	Public
R&I	Research and Innovation
RACER	Relevant, Accepted, Credible, Easy and Robust
SAF	Sustainable Aviation Fuel(s)
SDG	Sustainable Development Goal
SESAR	Single European Sky Air Traffic Management Research
S.M.A.R.T.	Specific, Measurable, Attributable, Relevant and Time-bound
SME	Small to Medium Enterprise
STATFOR	Statistics and Forecast Service
TAXUD	Taxation and Customs Union
TE	Technology Evaluator
TEAM_Play	Tool Suite for Environmental and Economic Aviation Modelling for Policy Analysis
TMA	Terminal Manoeuvring Area
TML	Transport & Mobility Leuven
TRL	Technology Readiness Level
UC	Use Case
UK	United Kingdom
UN	United Nations
US	United States (of America)
WHO	World Health Organisation

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1. INTRODUCTION

The main objective of the EC project "Impact Monitor" is to deliver a coherent and holistic Toolbox and Framework that aim to become the reference choice for technology and policy assessment and monitoring of the environmental-, economic- and societal-impact of European aviation R&I. Given the wide range of European aviation R&I, the best way to perform an impact assessment or monitoring varies from case to case. Although this variation may exist, all impact assessments and monitoring must answer a set of key questions and respect a number of principles.

Within the context of the Impact Monitor project, an impact assessment is considered to be a structured and holistic gathering and analysis of evidence of impacts of the R&I addressed. An impact monitoring is considered to be a regular, organised and holistic process of systematically collecting evidence throughout the development cycle of such R&I to oversee its progress. Hence, reliable evidence is a cornerstone of any impact assessment or monitoring. Evidence can refer to data, information and knowledge from various sources, including quantitative data (e.g. statistics, calculations, and measurements) and qualitative data (e.g. scientific and expert advice). Whenever possible, the evidence collected and used should be FAIR: Findable by anyone using common search facilities, Accessible so that data can be examined, Interoperable so that comparable data can be analysed and integrated through common vocabulary and open formats, and Reusable by other researchers or the public. As a result, the impact-assessment or -monitoring process becomes more transparent and more informed decisions can be taken.

The present document presents the Impact Monitor Toolbox and explains what conducting holistic impact assessments and monitoring entails while being targeted, effective, easy to comply with, and with the least burden possible. Hence, it focuses on the aforementioned key questions and principles to support evidence-based decision-making. More specifically, the toolbox provides a systematic approach of the complete cycle of performing impact assessments and monitoring of European aviation R&I. Or in other words, it is a way of working by setting out the requirements for the key steps in this cycle and providing practical, hands-on guidance and operational details. As such, it aims to provide support in efficiently, effectively and transparently conducting high-quality impact assessments and monitoring, and thus, in providing the best available evidence to enable stakeholders to take informed decisions.

The Impact Monitor Toolbox is especially inspired by the EC's Better Regulation Guidelines & Toolbox (cf. [8] & [9]) and, while noting Better Regulation deals with creating legislation, could be regarded to a very large extent as a tailored and paraphrased version thereof[1]. Nevertheless, it also capitalises on work for instance, in ECAC/ANCAT-MITG and in EU projects TEAM_Play [28], Technology Evaluator in Clean Sky 1 & 2 [2], and SESAR [27].

[1] For the sake of readability, in the main body of the present document no explicit reference is made and no quotation marks are used, in the (many) cases where text from the Better Regulation Toolbox is reused or paraphrased

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Adopting the terminology from Better Regulation, the practical, hands-on guidance, tips, and best practice are henceforth referred to as '*tools*' (which should not be confused with calculation/ simulation models or software tools).

The present document is organised as follows. Section 2 defines the basic impact-assessment and -monitoring process flow together with the organisation to maintain, update and apply the Impact Monitor Toolbox (and Framework). Sections 3-6 specify the tools for each step in this process flow: Specification, Set-up, Execution, and Analysis, respectively. Section 7 concludes the document, summarising the information provided herein. Finally, with the Impact Monitor Toolbox essentially based on the EC's Better Regulation Toolbox (as can be deduced from many of the tools specified in the present document), Appendix A presents a mapping of the Impact Monitor Toolbox onto the Better Regulation Toolbox.

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2. TOOLBOX: ASSESSMENT-PROCESS FLOW, BASICS AND ORGANISATION

The Impact Monitor project aims to deliver a coherent and holistic Toolbox and Framework that aim to become the reference choice for technology and policy assessment and monitoring of the environmental-, economic- and societal-impact of European aviation R&I. Thus, its main application focuses on assessing and monitoring the impact of such R&I, herewith supporting European policy-making for R&I in aviation.

With the wide range of European aviation R&I, the best way to perform an impact assessment or monitoring varies from case to case. Despite this variation, all impact assessments and monitoring must answer a set of key questions and respect a number of principles. The Impact Monitor Toolbox aims to capture these answers and principles through practical, hands-on guidance and operational details (or simply denoted by as '*tools*'). That is, the toolbox is a way of working by setting out the key steps in any assessment or monitoring cycle, and by presenting guidance, tips, and best practice, in order to aim for providing the best available evidence to enable stakeholders to take informed decisions. It is not expected to apply each individual tool to any impact assessment or monitoring, but to use the toolbox selectively and with common sense.

Essentially, the complete cycle of performing impact assessments or monitoring can be regarded to consist of four key steps as visualised in Figure 1:

1. Assessment or monitoring specification;
2. Assessment or monitoring set-up;
3. Assessment or monitoring execution; and
4. Assessment or monitoring analysis.

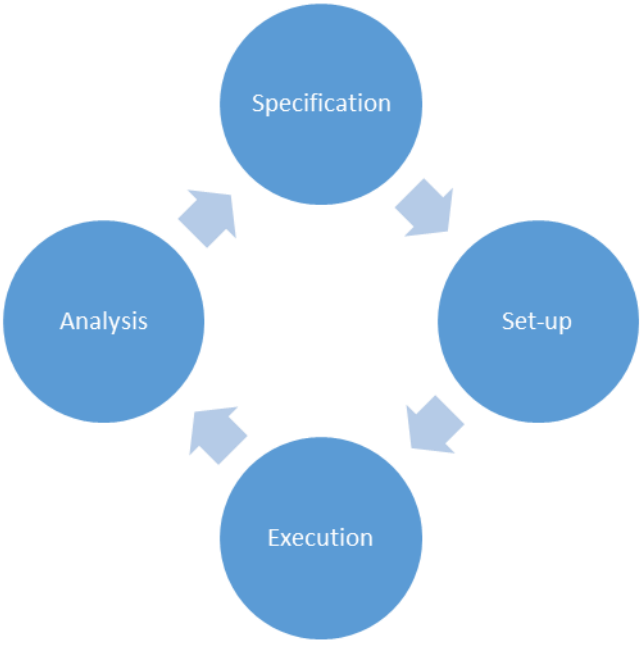

Figure 1. Impact Monitor Assessment- or Monitoring-process Flow

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The tools per step are described in Sections 3-6, respectively. To enable the specification of these tools, a set of fundamentals and principles for impact assessments and monitoring are to be defined, as well as a structure with the key organisational bodies involved in impact assessments and monitoring. These fundamentals and principles and this organisation are captured through tools described in Section 2.

Tool #1: What is impact assessment

An impact assessment is a process comprising a structured and holistic gathering and analysis of evidence of the impact of European R&I in aviation. Typically, the types of R&I concern technological developments, operational advancements, sustainable aviation fuels/propulsion, or policy options[2] addressed in Horizon Europe, including Clean Aviation, SESAR 3 and Clean Hydrogen. An impact assessment can be conducted at any stage in an R&I development cycle.

Evidence refers to data, information and knowledge from multiple sources, including quantitative data from statistics, calculations and measurements as well as qualitative data from scientific and expert advice. Reliable evidence is based on appropriate methods to collect, interpret, process and transform data and information, while transparently accounting biases and uncertainties. The evidence should be proportionate and appropriate for assessing the impact of the R&I (see also Tool #12).

Impact assessments aim to support policymaking (through science-based informed decision-support) for European R&I in aviation. In particular, European aviation R&I policy contributing to bridging the gap between R&I, regulatory framework and economic investments (with emphasis on climate neutrality by 2050 and European competitiveness), to better connecting European aviation R&I with education and skills, and to better communicating this R&I to citizens and stakeholders. Therefore, holistic impact assessments potentially address the full range of sustainable, environmental, economic and societal impacts, and support the complete aviation sector (including governments and society).

In the present context, impact assessments are considered to be carried out upon request; see also Tool #5.

> *The use cases demonstrated in the Impact Monitor project are examples of simple impact assessments (cf. [22]):*
> - *UC1: Impact of future SAF fuelled novel aircraft concepts with advanced propulsion systems;*
> - *UC2: Impact of an implementation of continuous descent operations;*
> - *UC3: Impact of different policies for the uptake of sustainable aviation fuels (SAF).*

Tool #2: What is impact monitoring

An impact monitoring is a regular or even continuous process comprising a systematic collection of evidence[3] in an organised and holistic way throughout the development cycle of a European R&I in aviation to oversee its progress. In general, impact monitoring involves tracking progress

[2] In case of policies at EU level, EC's Better Regulation applies to all EC's DGs and Services
[3] Evidence is to be understood as in Tool #1

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with respect to previously identified targets or objectives. Hence, it can serve as an early warning system (e.g. in case of unexpected outcomes that may suggest a need for adjustments) and feed into the R&I's development cycle. The types of R&I monitored span the same range as in Tool #1, but (as monitoring focuses on overseeing progress) the range of impacts to be monitored might be less broad than for an impact assessment.

In the present context, impact monitoring is considered to be carried out upon request; see also Tool #5.

> *The use cases demonstrated in the Impact Monitor project are examples of simple impact assessments (cf. [22]). Yet they may also be regarded as examples of simple impact monitoring, when considering the development of the R&I to be in progress.*

Tool #3: Fundamental of impact assessment or monitoring

The fundamental principle of any impact assessment or monitoring of a European R&I in aviation is the comparison of the same set of impacts between two scenarios in a specific future year. The first scenario (or Reference Scenario) is a future projection of the (relevant part of the) air-transport system in that year based on autonomous economic, demographical and technological developments but without the R&I under investigation. The difference in the second scenario (or R&I Scenario) is the introduction of this R&I. The Reference Scenario and R&I Scenario are future projections of a (so-called) Baseline Scenario, which reflects the actual state of the (relevant part of the) air-transport system in a historic year.

An impact assessment or monitoring addresses one or more of the following assessment or monitoring levels:

- Aircraft level;
- Airport level;
- Air-transport system level.

> *Each use case demonstrated in the Impact Monitor project (cf. [22]) compares the impacts in 2050 of a Reference Scenario with those of an R&I Scenario, and addresses aircraft level (UC1), airport level (UC2) and air-transport system level (UC3). The Reference Scenario and R&I Scenario are future projections of the Baseline Scenario that reflects the actual state in 2019.*

Tool #4: Principles in impact assessment or monitoring

Every impact assessment or monitoring of a European R&I in aviation is governed by a set of common principles and (see Sections 3-6) follows a systematic and structured process. These principles and this process help to provide a rigorous evidence base to inform decision making, to make R&I development and policy in European aviation more effective, coherent and efficient, and to enhance transparency. Impact assessments and monitoring should therefore be:

- Embedded in the development cycle for (policy for) European R&I in aviation, i.e. their evidence should feed into the development process of (policy for) R&I;

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- Of high quality, e.g. as supported by tools (i.e. guidance, tips, and best practice) of the Impact Monitor Toolbox;
- Evidence-based, i.e. their outcomes should be based on the best available evidence, and thus, they should be founded on science and expert knowledge. Once again, evidence refers to quantitative data from for instance, statistics, calculations and measurements, and from reliable, trustworthy and recognised sources as well as to qualitative data from scientific and expert advice. Consequently, existence of various types and sources of data and models should be acknowledged; the method used to collect, interpret, analyse, process and transform data should be clarified; the degree of (scientific) uncertainty should be addressed; and why some evidence may not be available should be transparently explained as well as how this may affect the assessment or monitoring. Whenever possible, evidence collected and used should be Findable, Accessible, Interoperable and Reusable (FAIR): Findable by anyone using common search facilities, Accessible so that data can be examined, Interoperable so that comparable data can be analysed and integrated through common vocabulary and open formats, and Reusable by other researchers or the public;
- Strategic foresight, i.e. they should integrate projections of the future in a structured and systematic way (and be reflected in Reference and R&I scenarios);
- Proportional, i.e. they should be proportionate to, for instance, the scope, objective/target, potential impact, and TRL of the R&I;
- Comprehensive, i.e. their outcomes should cover all relevant (sustainable, environmental, economic, and societal) impacts;
- Coherent, i.e. they should be conducted coherently across different R&I domains;
- Transparent, i.e. their underlying process, assumptions, methodologies, and data and model sources should be transparent to all stakeholders involved in, impacted by or served by the R&I; transparency is important to ensure understanding and credibility of the impact assessment or monitoring;
- Impartial, i.e. their outcomes should serve R&I (policy) decisions – not the other way around;
- Appropriately resourced and organised, i.e. sufficient time and (human and financial) resources should be available to deliver a timely and high-quality result;
- State of the art, i.e. they should be based on the latest scientific state of play in the associated impact assessment or monitoring regarding for example, the methodologies applied as well as the data and models used.

Various of the aforementioned principles for impact assessments and monitoring are elaborated in tools in Sections 3-6.

> *Illustrations of Tool #4 are provided in Sections 3-6 for the use cases demonstrated in the Impact Monitor project (cf. [22]) or (in case not appropriate for these use cases) for another application.*

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Tool #5: Organisational bodies in impact assessment or monitoring

To coordinate the maintenance, updating and application of the Impact Monitor Toolbox and Framework for holistic environmental-, economic and societal-impact assessments or monitoring of European aviation R&I, three organisational and permanent bodies are established:

- Steering Committee;
- Advisory Committee;
- Pool of Excellence.

The aim of these bodies is to ensure the set of principles in Tool #4 is respected as well as to ensure a proper and suited approach (i.e. these bodies have different roles and responsibilities, and therefore constitute of different members). In addition to these three bodies, a Model Catalogue is established and maintained. Figure 2 sketches the organisational structure with interactions and main steps in an impact-assessment or -monitoring cycle, which is elaborated below.

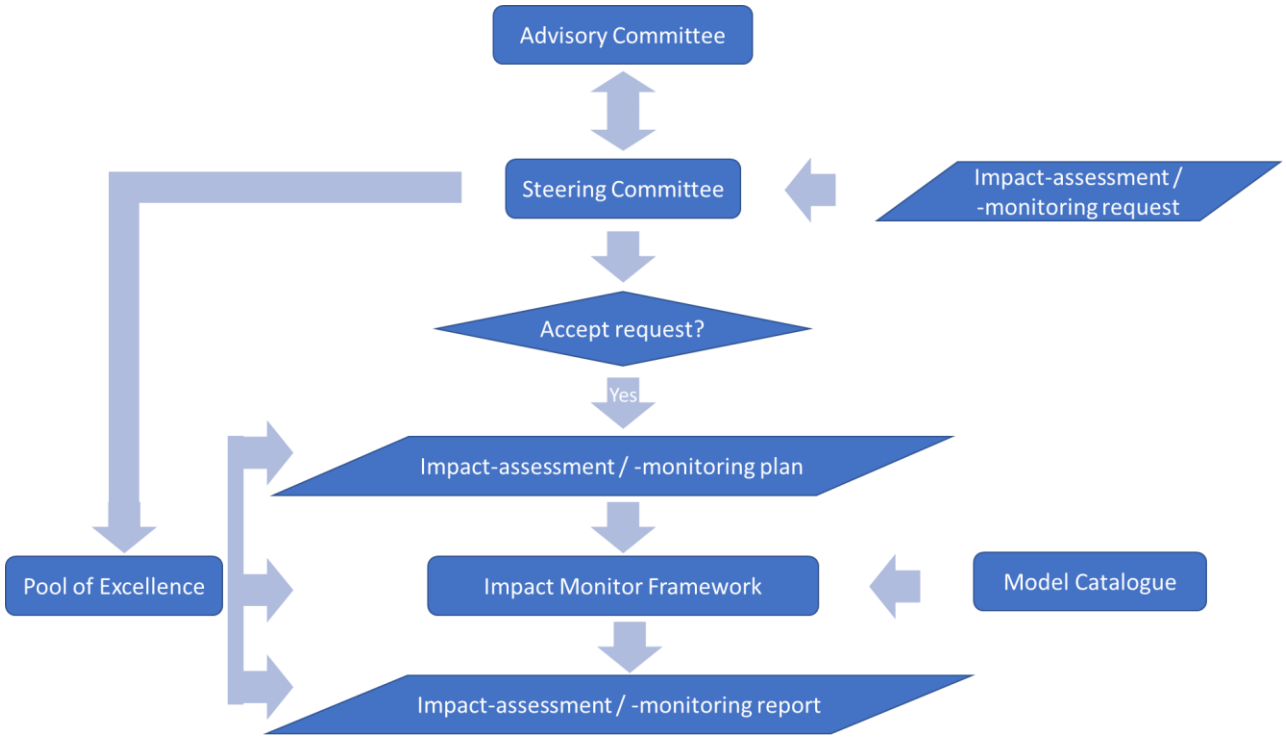

Figure 2. Impact Monitor Assessment or Monitoring: Organisation

Steering Committee

The Steering Committee is the overarching body to coordinate and supervise the Impact Monitor Toolbox and Framework, but also to establish and maintain contact with key stakeholders and (with the support of the Advisory Committee) to lobby for holistic impact-assessment and -monitoring projects and for basic funding to maintain the Impact Monitor Toolbox and Framework.

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The main roles of the Steering Committee include:

- To maintain and update the Impact Monitor Toolbox;
- To coordinate and harmonise the Impact Monitor Framework:
  - Specify, maintain and apply a process to adopt (candidate) models for the Model Catalogue;
  - Ensure the Model Catalogue is state of the art;
  - Ensure the Impact Monitor Framework offers adequate capabilities and services;
  - Ensure the Impact Monitor Framework supports holistic impact assessments and monitoring, is redundant, and has standardised interfaces;
  - Lobby and fundraise to maintain and update/enhance the Impact Monitor Framework;
  - Establish a legal framework for model and data protection.
- To implement a quality management system for impact assessments and monitoring, based on well-established standards (such as from ISO (e.g. its 9000 and 14000 families) and AQAP), to monitor its application in impact assessments and monitoring, and to keep it up to date;
- To supervise and monitor the complete assessment or monitoring cycle per impact-assessment/-monitoring study (including to appoint the lead per impact-assessment/-monitoring request and study), and to implement in the Impact Monitor Toolbox the lessons learnt from assessment or monitoring studies;
- To interact with and consult the Advisory Committee;
- To contact and maintain relationships with key actors/stakeholders in European aviation R&I, and advise them on aviation modelling trends and requirements;
- To coordinate the Pool of Excellence;
- To act as initial link between customers and the Pool of Excellence;
- To provide regularly (e.g. yearly) management reports to the European Commission (e.g. on developments in the Impact Monitor Toolbox and Framework, on model developments, on assessment/monitoring requests accepted (and not accepted), and on assessment studies conducted).

The Steering Committee shall be composed of one representative per EREA member in the present Impact Monitor consortium: DLR, ONERA, NLR, and CIRA.

Advisory Committee

The Advisory Committee advices the Steering Committee in order to support the latter in fulfilling its roles. The main roles of the Advisory Committee include:

- To advise on updating/enhancing the Impact Monitor Toolbox;
- To advise on updating/enhancing the Impact Monitor Framework, e.g. on:

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  - Capabilities of the Impact Monitor Framework;
  - New models (developments) for adoption in the Model Catalogue;
  - Aviation modelling methodologies, scenarios (and assumptions), needs and requirements.
- To support communication and promotion of the Impact Monitor Toolbox and Framework, e.g.:
  - Suggest key actors/stakeholders in European aviation R&I and support in establishing (initial) contacts/relationships;
  - Establish contact with potential projects, partners, customers and fundraising opportunities;
  - Support the claim of the Model Catalogue being state of the art and maintaining this claim;
  - Communicate successful impact-assessment and -monitoring studies and their outcomes.
- To advise on handling impact-assessment and -monitoring requests and formulating/ specifying impact-assessment and -monitoring studies.

Candidate members of the Advisory Committee are representatives from:

- European Commission;
- EU Research Programmes (e.g. Clean Aviation, SESAR 3, and Clean Hydrogen);
- ACARE;
- EASA;
- EEA;
- EUROCONTROL's Performance Review Commission;
- ECAC;
- ACI Europe;
- IATA;
- ICAO-CAEP's European Member States;
- Research networks focusing on state of the art in impact-assessment/-monitoring modelling and data (e.g. ECATS and ANCAT).

For a successful Advisory Committee, the representatives of its members should be actively involved and have a pro-active attitude (both in the Advisory Committee and in their respective organisations).

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Pool of Excellence

The main roles of the (open) Pool of Excellence are:

- To perform environmental-, economic- and societal-impact assessments and -monitoring of European aviation R&I through the Impact Monitor Toolbox and Framework in order to assist the EC, EU Member States / Associated Countries, and EASA in ICAO Working Groups and other international regulatory agencies;
- To increase transparency and coherence of Reference Scenarios;
- To maintain and update existing models to ensure these are state of the art (e.g. fully compliant with the latest (applicable) EU Directives, international (scientific) standards, and recommended and best practices) and to develop and validate new models to enable performing the requested environmental-, economic- and societal-impact assessments and monitoring of European aviation R&I;
- To maintain and update/enhance the Impact Monitor Framework;
- To monitor developments in EU Directives, international (scientific) standards, and recommended and best practices for environmental-, economic- and societal-impact assessments and monitoring of aviation R&I (e.g. through the participation in international research networks such as ECATS and ANCAT, and the organisation of meetings with international counterparts).

At present the Pool of Excellence potentially comprises experts from the organisations founding the Impact Monitor project: DLR, ONERA, NLR, CIRA, Cranfield University, University of Stuttgart, Transport & Mobility Leuven, University of Patras, and Polytechnical University of Catalonia. The Pool's areas of expertise include (environmental, economic and societal) modelling, IT, impact assessments and monitoring, consultancy, and communication.

The Pool of Excellence will evolve over time: On the one hand with additional experts from the currently participating organisations and on the other hand with experts from organisations not yet participating in the consortium; But also, through experts or organisations retiring.

The Steering Committee coordinates the composition of the Pool of Excellence. To this end, it shall establish and maintain a capability and competence matrix for (candidate) organisations participating in the Pool of Excellence, specify dedicated dissemination activities, and reach out specifically to relevant model owners. Further, to extend the Pool of Excellence, the Steering Committee could reach out to modelling experts and model owners through for instance, dedicated dissemination activities, contacts already established from previous projects in which members of the Impact Monitor consortium participated, and contacts from other previous projects they are aware of.

> *The Pool of Excellence might be considered the Impact Monitor project's counterpart of the EC's Competence Centre on Modelling (CC-MOD; [25]).*

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Model Catalogue

In general, a model is a stylised representation of the real world that is used to make projections or to evaluate the behaviour of a system under specific assumptions. Models can provide support, insight and understanding to stakeholders of the R&I under consideration. A good model selection and use are crucial to deliver high quality and relevant results. Within the scope of the Impact Monitor project, a wide variety of model categories is relevant, underpinning the relevance of multi-disciplinary and integrated modelling approaches. An overview of all categories is well beyond the scope[4].

The Impact Monitor Model Catalogue consists of all models that are selected as candidate for application in an impact assessment or monitoring. This may include models not yet available to the Pool of Excellence. The adoption of a model to the Model Catalogue is the responsibility of the Steering Committee. For this adoption, the Steering Committee shall specify a transparent set of criteria by establishing a matrix that is composed of three pillars: Key-performance Areas (KPAs), assessment/monitoring objects (i.e. aviation R&I), and assessment/monitoring levels:

- KPAs: The Impact Monitor project provides an (initial) set of KPAs (see Tool #9);
- Assessment/monitoring objects: The Impact Monitor project considers aviation R&I in the realm of aircraft technology and concepts, of ATM, operations and infrastructure, of sustainable and alternative aviation fuels/propulsion, and of policies and regulations;
- Assessment/monitoring levels: The Impact Monitor project considers the three assessment/ monitoring levels: Aircraft, Airport, and Air-transport system (cf. Tool #3).

Any candidate for the Model Catalogue shall address or (e.g. in case of models to develop scenarios) support at least one aspect in each of the three pillars. Furthermore, it shall at least be state of the art, be sound from a scientific point of view, be transparent from the perspective of stakeholders, be of high quality, be documented, be able to interface with the Impact Monitor Framework, and be linked to one or more experts in the Pool of Excellence.

Models available to the current Impact Monitor consortium and in the ECAC / MITG model inventory are considered for the initial list of candidates for possible inclusion in the Model Catalogue[5]. When a model in this catalogue is applied for the first time in an impact assessment or monitoring, it will be connected to the Impact Monitor Framework by the existing or an expanded Pool of Excellence.

> *The models selected for the use cases demonstrated in the Impact Monitor project (cf. [22]) have not been subject to a formal adoption process and therefore, they cannot yet be considered to be adopted to the Impact Monitor Model Catalogue 'officially'.*

[4] Examples of potentially relevant model categories are provided in Appendix B
[5] Appendix B provides an initial list of candidate models for potential adoption to the Model Catalogue

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3. TOOLBOX: ASSESSMENT AND MONITORING – SPECIFICATION

The specification of an impact assessment or monitoring addresses various topics, such as properly understanding the impact-assessment or -monitoring request, preparing a (global) impact-assessment or -monitoring plan, and deciding whether or not to accept the request. The tools associated with this specification (as listed below) do not have to be applied in the order of their appearance. As a rule of thumb, their order of application could generally be as depicted in Figure 3.

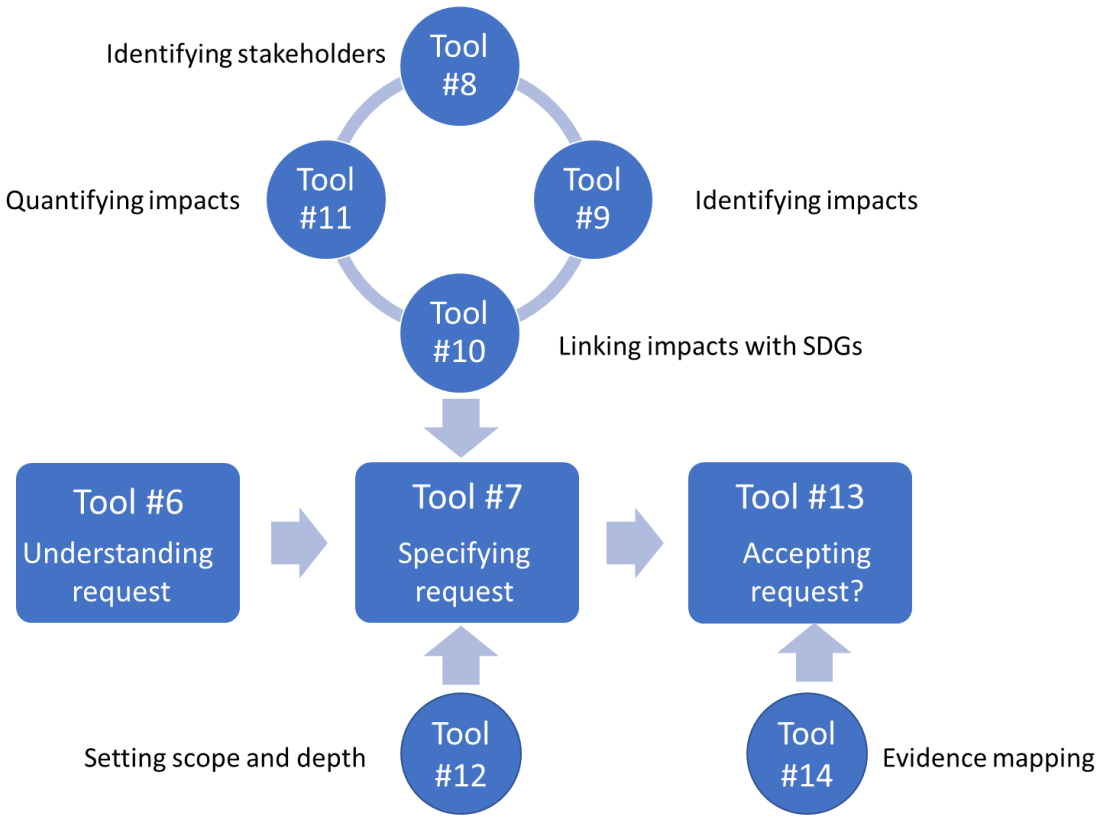

Figure 3. Impact Monitor-assessment and -monitoring Specification – General Schema

Tool #6: Understanding impact-assessment or -monitoring request

It is recommended to have a complete understanding of the European aviation R&I requested to be assessed or monitored. This especially concerns a profound understanding of:

- What this R&I encompasses;
- Aim, purpose and/or objective[6] as well as context of this R&I;

[6] Objectives should be S.M.A.R.T.: Specific (i.e. they are precise and concrete), Measurable (i.e. they define future impacts or states in measurable terms), Attributable (i.e. they define a change in future impacts or states that is attributable to the R&I), Relevant (i.e. they are directly linked to the R&I), and Time-bound (i.e. they relate to a precise time horizon)

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- Expected impact of this R&I;
- Stakeholders categories involved in, served by and/or impacted by this R&I.

Thus, engaging both the developers and stakeholders of the R&I to be assessed or monitored is highly beneficial for such understanding and consequently, for ensuring the requested assessment or monitoring is correctly interpreted and well understood.

The outcome of this tool is the scope and context of the impact assessment or monitoring of the R&I, through a specification of the underlying research question(s).

> *Due to their objective, Tool #6 is only touched upon in the description of the use cases demonstrated in the Impact Monitor project (cf. [22]). A better example of the application of the tool can be found in (amongst other programmes and projects) SESAR (cf. [27]). There, it entails the understanding of the new ATM concept and the scenarios for implementation. Information collected includes a high-level description of the current and new ATM concept (and so, their differences), the operational improvement SESAR is looking for, the expected environmental impact of the new concept, and the phases of flight affected by the new concept. Moreover, the importance of engaging with stakeholders is emphasised.*

Tool #7: Specifying impact assessment or monitoring

With the underlying research question(s) of the requested impact assessment or monitoring well understood through Tool #6, the impact assessment or monitoring of the European aviation R&I concerned is specified. This specification generally details at least the following questions (a few that are already touched upon in Tool #6):

- What R&I is to be assessed or monitored?
- What problem does this R&I aim to (help to) alleviate?
- What does this R&I aim to achieve?
- What is the development stage of this R&I (e.g. TRL)?
- What stakeholders are (or could be) involved in, served by and/or impacted by this R&I? See Tool #8 for further guidance;
- What assessment levels are to be considered (i.e. aircraft, airport and/or air-transport system level) for this R&I?
- What is the year for the Baseline Scenario and what is (are) the year(s) for the Reference and R&I Scenario(s) for this R&I?
- What key-performance indicators are to be quantified for this R&I? See Tools #9, #10 and #11 for further guidance;
- What instruments (e.g. EU Directives and international (scientific) standards, and recommended and best practice) are applicable for assessing or monitoring this R&I?

The outcome of this tool is a specification of the impact assessment or monitoring of the R&I with its year(s) for the Baseline, Reference and R&I Scenarios.

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> *The use cases demonstrated in the Impact Monitor project are specified in the Impact Monitor deliverable D5.2 [22], herewith touching upon many of the questions addressed above.*

Tool #8: Identifying stakeholders of impact assessment or monitoring

Taking the interests of all stakeholders or stakeholder categories into consideration can contribute to more credible and transparent impact assessments or monitoring. To identify all stakeholders (i.e. all stakeholders who are involved in, impacted by or served by the European aviation R&I to be considered) or stakeholder categories, the following questions can be used for a structured approach[7]:

- Who is directly involved in, impacted by or served by the R&I?
- Who is indirectly involved in, impacted by or served by the R&I?
- Who is potentially involved in, impacted by or served by the R&I?
- Whose help or support is needed to realise and/or implement the R&I?
- Who has knowledge or know-how about the subject area of the R&I?
- Who has an interest in the subject area of the R&I?

The outcome of this tool is a list of (categories of) stakeholders who are involved in, impacted by or served by the R&I to be assessed or monitored. In addition, this list could be sorted according to the level of being involved, impacted and/or served, with the aim to focus first on the stakeholders who are mostly involved, impacted and/or served.

> *The Impact Monitor deliverable D2.2 [18] provides an initial list of potential stakeholders in impact assessments of European R&I in aviation. Main examples are European Commission (through several of its DGs and Agencies), EU Member States (through their ministries), research institutes and academia, environmental and regulatory agencies, aviation industry (including airports and airlines), and European (national and international) research programmes.*

Tool #9: Identifying impacts for impact assessment or monitoring

The core of any impact assessment or monitoring is the identification, quantification and analysis of the most significant[8] impacts of the European aviation R&I to be addressed. The impacts focus on environment/sustainability, economics and/or society. Therefore, it is important to ensure that the assessment or monitoring focuses on the most important impacts for each specific case, in line with the principle of proportionate analysis (cf. Tools #4 and #12).

With the stakeholders or stakeholder categories identified in Tool #8, the potential impacts of the assessment or monitoring are screened by addressing how they are or can be affected (either directly or indirectly). The following table lists key impacts that may serve the purpose for this screening (with a 'tick' denoting an indicative dominant category of impact).

[7] www.consultationinstitute.org/challenge-consulting-many-stakeholder-identification/

[8] Appreciation of what is considered 'significant' depends on expert judgement and should take into consideration results of associated assessments or monitoring

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Impact of R&I on	Environment / Sustainability	Economics	Society
Climate • Does R&I affect emissions of greenhouse gasses into atmosphere? • Does R&I affect emissions of ozone depleting substances? • Does R&I affect economic incentives set up by market-based measures (e.g. ETS)? • Does R&I affect ability to adapt to climate change?	✓		
Air quality • Does R&I affect emissions of acidifying, eutrophying, photochemical or harmful air pollutants that might affect human health or lead to deterioration of environment?	✓		
Working conditions, job standards and quality • Does R&I affect occupational health and safety? • Does R&I affect labour cost or standards? • Does R&I affect quality of work conditions?			✓
Public health and safety • Does R&I affect health and safety of individuals/populations through impact on socio-economic environment? • Does R&I increase or decrease likelihood of health risks? • Does R&I affect health due to changes in amount of noise and air quality? • Does R&I have specific effects on particular risk groups?			✓
Education and training • Does R&I affect level of education or training outcomes? • Does R&I affect skills used by individuals? • Does R&I affect education and mobility of workers?		✓	✓
Conduct of business • Does R&I impose additional cost on business? • Does R&I affect cost or availability of essential inputs? • Does R&I affect investment cycle? • Does R&I entail withdrawal of certain products from market? • Does R&I entail stricter regulation of conduct of particular business? • Does R&I lead to creating new or closing down businesses?		✓	
Position of small to medium enterprises (SMEs) • Does R&I affect operation and competitiveness of SMEs?		✓	
Administrative burden on business • Does R&I affect nature of information obligations placed in businesses?		✓	
Sectorial competitiveness • Does R&I affect cost of doing business? • Does R&I have productivity effects? • Does R&I affect business' capacity to innovate? • Does R&I affect business' market share and competitive advantages? • Does R&I affect international standards and common regulatory approaches?		✓	

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Impact of R&I on	Environment / Sustainability	Economics	Society
Public authorities • Does R&I have budgetary consequences for public authorities? • Does R&I bring additional administrative cost to public authorities? • Does R&I require creation of new or restructuring existing public authorities?		✓	
Sustainable consumption/use and production • Does R&I lead to more sustainable production and consumption? • Does R&I change relative prices of environmentally friendly and unfriendly products? • Does R&I promote or restrict environmentally friendly and unfriendly goods and services? • Does R&I lead to business becoming more, or less polluting through changes in the way they operate?	✓	✓	
Efficient use of resources (renewable and non-renewable) • Does R&I affect use of renewable resources and lead to their use being faster than they can regenerate? • Does R&I reduce or increase use of non-renewable resources? • Does R&I lead to changes in business opportunities linked with more efficient use of resources?	✓		✓
Employment • Does R&I lead to creation or loss of (new or direct) jobs? • Does R&I lead to factors that would prevent or enhance potential to create jobs or prevent job losses? • Does R&I influence opportunities or incentives of workers or specific groups to work? • Does R&I have overall consequences for economic growth and employment?		✓	✓
Technological development and digital economy • Does R&I affect processes that could be simplified or automated? • Does R&I potentially create synergies with existing digital policies? • Does R&I affect pace of digital transformation of economic or societal sectors?		✓	✓
Innovation and research • Does R&I hinder or stimulate research and development? • Does R&I facilitate introduction and dissemination of new production methods, technologies, and products? • Does R&I promote or limit academic or industrial research? • Does R&I promote greater productivity/resource efficiency?	✓	✓	✓
Resilience and technological sovereignty • Does R&I affect EU resilience in associated R&I area? • Does R&I improve or hinder sovereignty of EU?			
Transport and use of energy • Does R&I affect energy intensity of economy? • Does R&I affect fuel mix used in energy production?	✓	✓	✓

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Impact of R&I on	Environment / Sustainability	Economics	Society
• Does R&I increase or decrease demand for transport or influence its modal split? • Does R&I increase or decrease energy and fuel needs/consumption?			
Waste production, generation and recycling • Does R&I affect waste production or how waste is treated, disposed of, or recycled?	✓	✓	✓
Sustainable development • Does R&I contribute to sustainable development?	✓	✓	✓

It is not necessary to examine all impacts for all possible stakeholders. The most relevant or significant ones should be pragmatically identified based on the proportionality analysis (see Tool #12). Factors to be considered in the selection of impacts (in terms of changes relative to the Reference Scenario) include:

- Relevance of the impact;
- Magnitude of the expected impact (both in absolute terms and in relative size for specific stakeholders or stakeholder groups);
- Sensitivity of the impact.

All significant impacts should be assessed. The analysis should be quantified as far as possible (though in a proportionate manner), but when models or data are lacking for significant impacts, this should be complemented with or replaced by a qualitative analysis.

> *The impacts considered in the use cases demonstrated in the Impact Monitor project (cf. [22]) focus on noise, gaseous emissions, local air quality, health, safety, use of energy, and conduct of business.*

Tool #10: Linking with SDGs in impact assessment or monitoring

EC put the United Nations' Sustainable Development Goals (SDGs) at the heart of its policymaking. To enable the monitoring of the EU's progress towards these goals, indicators for an impact assessment or monitoring of a European R&I in aviation should be linked with SDGs. The 17 SDGs are:

1. No poverty;
2. Zero hunger;
3. Good health and wellbeing;
4. Learning and education;
5. Gender equality;
6. Clean water and sanitation;

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7. Affordable and clean energy;
8. Decent work;
9. Industry and innovation;
10. Reduced inequalities;
11. Sustainable cities;
12. Consumption and production;
13. Climate action;
14. Life below water;
15. Life on land;
16. Peace, justice and strong institutions;
17. Partnerships for the goals.

Using the table from Tool #9, the following table provides an initial mapping of impact onto SDGs. This table (and the UN's indicator list [29]) may help in detailing the link between each indicator and relevant SDG(s)[9].

Impact of R&I on	SDG
Climate	7, 13
Air quality	3, 11, 13, 15
Working conditions, job standards and quality	8, 10
Public health and safety	3
Education and training	4, 8
Conduct of business	8, 9, 12, 17
Position of small to medium enterprises (SMEs)	8, 9
Administrative burden on business	8
Sectorial competitiveness	8, 9, 10, 17
Public authorities	16
Sustainable consumption/use and production	8, 12
Efficient use of resources (renewable and non-renewable)	6, 7, 8, 12, 14, 15
Employment	8
Technological development and digital economy	8, 9
Innovation and research	8, 9, 17
Resilience and technological sovereignty	4, 6, 8, 9, 12,13,14,15, 17
Transport and use of energy	7, 8, 11, 12
Waste production, generation and recycling	12

[9] EC has a platform to support the evidence-based implementation of SDGs (cf. [12])

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Tool #11: Quantifying impact in impact assessment or monitoring

There is a vast range of indicators to quantify the wide variety of possible impacts in an impact assessment or monitoring of a European R&I in aviation. An indicator can give only one perspective of the performance of the R&I. Hence, a set of indicators ought to be selected carefully, while being aware of their limitations and possible burden for their modelling and data collection.

Indicators should be selected in such a manner to provide relevant and reliable information proportionally to the scope and depth of the analysis (cf. Tool #12). All indicators should be chosen based on a set of clear criteria. To the extent possible, all indicators should be RACER:

- Relevant, i.e. closely linked to the assessment or monitoring objectives;
- Accepted, e.g. by stakeholders;
- Credible, e.g. for non-experts, unambiguous and easy to interpret;
- Easy to monitor;
- Robust.

Besides the RACER criteria, other important criteria to consider include:

- Attributable, i.e. changes in the indicator should be attributable to the R&I;
- Models and data should be easily/readily available, of a good quality, and at the appropriate assessment or monitoring level (i.e. aircraft, airport and/or air-transport system level);
- Indicators definition should come with the unit of measurement;
- Legal framework for models and data protection (cf. Tool #5).

It is always important to understand and explain the limitations of the indicators. Further, where impacts concern complex multidimensional concepts such as quality of life or wellbeing, composite indicators may be useful, as they aggregate a set of indicators into a single measure. However, as they often use predefined weight values, they may be difficult to interpret and are usually more suitable for assessing the broad context.

Appendix C lists an initial set of sustainable, economic and societal indicators for potential use in quantifying impact in assessments or monitoring of European R&I in aviation. Note that a few indicators may be mandatory (e.g. in light of EU Directives, EASA regulations or ICAO standards) or recommended (e.g. because of recommended and best practices). Appendix D presents a few examples on how to quantify several of the indicators in this indicator set.

> *Whenever applicable, the indicators selected in the use cases demonstrated in the Impact Monitor project (cf. [22]) are consistent with relevant EU Directives and recommendations (such as in UC2 (at airport level) Directive 2002/49/EC for noise (as reflected in ECAC's Doc 29 [4]-[6]) and ICAO's Doc*

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> *9889 [17] for emissions. Another example is taken once again from SESAR (cf. [27]). There, guidance is provided on which environmental impacts to investigate:*
>
> - *Local air quality (e.g. NO_X, PM, and SO_X): Emissions below 3,000 ft as a conservative upper limit (consistent with ICAO's recommendation in its Doc 9889 [17]);*
> - *Noise: 10,000 ft is considered the conservative upper limit for departures, while 7,000 ft is the upper limit for arrivals (in line with 2002/49/EC and ECAC's Doc 29 [4]-[6]);*
> - *Fuel burn and CO_2 should be investigated at any level of flight and for any phase of aircraft operation.*

Tool #12: Proportionality to impact assessment or monitoring

The scope and depth of the analysis in an impact assessment or monitoring of a European R&I in aviation should be proportionate and consistent with the importance, type and TRL of the R&I and with the nature and magnitude of the expected impact. This scope and depth should concentrate on what is relevant for informed decision-making and therefore, the analysis should provide answers to the key research questions (cf. Tool #6). That is, a separate and lighter impact assessment or monitoring does not exist.

The appropriate depth and scope of the impact assessment or monitoring are reflected through:

- Resources and time allocated to the complete cycle of the impact assessment or monitoring;
- Relative effort required to answer each of the research questions underlying the impact assessment or monitoring;
- Specific focus of each step in the analysis.

Setting the scope and depth of the analysis may therefore be an iterative process, and proportionality might have to be adjusted as the analysis evolves. The proportionate level of analysis varies from case to case but is influenced by general factors and relates to the nature of the R&I to be assessed or monitored. For example:

- Development stage of the R&I (think for instance of the R&I's TRL and the extent to which the R&I is disruptive or a breakthrough);
- Magnitude and complexity of the R&I;
- Significance of the expected impact of the R&I.

Tool #13: Decision on conducting impact assessment or monitoring

With an (initial) specification of the impact-assessment or -monitoring request (cf. Tool #7), the Steering Committee decides on whether or not to accept this request (cf. Tool #5). To this end and prior to the decision, additional information may be required (whenever necessary in consultation with the Advisory Committee and Pool of Excellence):

- Provisional identification of required expertise and capabilities

  Based on the underlying research questions, on the key-performance indicators to quantify, on the applicable instruments, and on the Baseline, Reference and R&I Scenarios, the

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Steering Committee identifies the required expertise and capabilities. This includes the provisional selection of candidate models from the Model Catalogue as well as the provisional identification of any model or data gap. These candidate models shall be fit for purpose (i.e. meet the minimum and maximum requirements regarding for instance, level of detail).

- Provisional list of experts and models

  Through a transparent process and based on the outcomes of the previous step, the Steering Committee selects the experts from the Pool of Excellence, the models from the Model Catalogue, and the way to overcome any data or model gap (e.g. acquiring a model with the required capability, update an appropriate model in the Model Catalogue, or use an appropriate model in the Model Catalogue such that it is fit for purpose). Selection criteria (though not necessarily equally weighted) include sufficient level of competence, quality, availability, cost-efficiency, and equity.

- Estimating required effort and timeline

  The Steering Committee prepares an overview of activities to answer the key research questions, including an initial estimate of the associated effort, time and cost as well as a list with proposed experts from the Pool of Excellence (which may be expanded with external experts; for instance, to overcome model or data gaps).

With the acceptance of an impact-assessment or -monitoring request, the experts from the Pool of Excellence (including the lead) are appointed, the models from the Model Catalogue are selected, and the model and data gaps to be filled are identified.

> *Tool #13 does not apply to the use cases demonstrated in the Impact Monitor project (cf. [22]). Therefore once more, an example from SESAR (cf. [27]) is taken. There, the project manager identifies the ATM changes due to the new concept and the scope of the potential impacts of this concept on the environment with respect to climate change, noise and local air quality. Consulting the supporting documentation of the new ATM concept, it is assessed whether or not the ATM change has an obvious environmental impact. If so, a decision to conduct an environmental-impact assessment is taken. If it is not clear, an expert judgement can be carried out to determine the potential environmental scope. Aspects related to the identification of, amongst others, models and scenarios are addressed after the decision.*

Tool #14: Evidence mapping for impact assessment or monitoring

Evidence mapping serves as a (quick) literature review of what is already known about assessing or monitoring the type of European aviation R&I under investigation. It may provide relevant information on what and how to assess this R&I, what further evidence needs to be collected, and what model and data gaps there might be.

An initial and quick overview may be obtained by addressing:

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- Impact assessments or monitoring of R&I in aviation in EU programmes/projects[10]

  For instance:

  - Aircraft technology and concepts: Technology Evaluator (TE) in Clean Sky 1 & 2, and impact monitoring in Clean Aviation;
  - ATM, operations and infrastructure: SESAR, SESAR 2020, SESAR 3, and ClimOP[11];
  - Sustainable and alternative aviation fuels/propulsion: Clean Hydrogen and Clean Aviation;
  - Policies and regulations: Green Deal, Fit-for-55, European Climate Law, Renewable Energy Directive, and ETS.

- Impact models for impact assessments or monitoring available or known to consortium

  Think of models considered in TEAM_Play, listed in ECAC / MITG's models' inventory, included in the Model Catalogue (cf. Tool #5), and available to the Impact Monitor consortium (cf. [21]).

- Impact-assessment or -monitoring methodologies in EU Directives, international standards, and recommended or best practices

  For example:

  - Aircraft level: Criteria in EASA aircraft certification and ICAO Annex 16;
  - Airport level: Directive 2002/49/EC, Regulation 598/2014, ICAO Doc 9889, E-OCVM, SESAR 2020 PJ19, EUROSTAT Quality of Life, ICAO Key Performance Areas air navigation, and TE in Clean Sky 1 & 2;
  - Air-transport system level: E-OCVM, SESAR 2020 PJ19, EUROSTAT Quality of Life, ICAO Key Performance Areas air navigation, TE in Clean Sky 1 & 2, European Aviation Environmental Report 2025, ICAO's Economic analysis and forecasts, ATAG Study on economic & social benefits of air transport, EASA study on non-CO_2 effects of aviation, and ICAO Environmental Report 2022.

> *Regarding the use cases demonstrated in the Impact Monitor project (cf. [22]), evidence mapping is largely based on:*
>
> - *UC1: TE in Clean Sky 1 & 2;*
> - *UC2: Methodologies from TE in Clean Sky 1 & 2, Directive 2002/49/EC, Regulation 598/2014, ICAO Doc 9889, and ICAO Doc 9184;*
> - *UC3: Clean Aviation.*

[10] An overview of recent and relevant projects is provided in the Impact Monitor deliverable D2.3 [19]

[11] cordis.europa.eu/project/id/875503

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4. TOOLBOX: ASSESSMENT AND MONITORING – SET-UP

With the specification of the impact-assessment or -monitoring request and the acceptance of this request by the Steering Committee, the next step is to set-up the impact assessment or monitoring. This step focuses on the preparation of an assessment or monitoring plan, the specification of the assessment or monitoring methods, and the specification of the Baseline, Reference and R&I Scenarios.

The order of appearance of the tools associated with the set-up of the impact assessment or monitoring (as listed below) does not (necessarily) correspond with the order of their application. Especially Tool #15 can only be completed once Tool #16 (but also Tools #17, #18 and #19) have been completed. For the sake of presentation, Section 4 starts with Tool #15 as it provides an overview of what information is needed to plan and prepare an impact assessment or monitoring. Figure 4 illustrates the general relationships between the tools addressed in this Section.

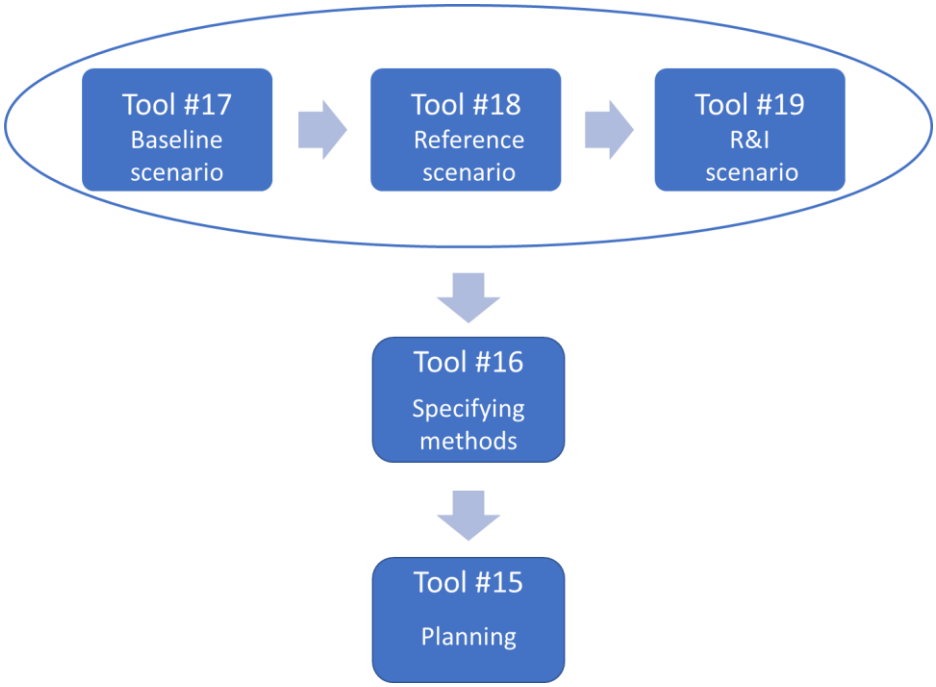

Figure 4. Impact Monitor-assessment and -monitoring Set-up – General Schema

Tool #15: Planning impact assessment or monitoring

Preparing and setting up an impact assessment or monitoring of a European R&I in aviation require careful planning and sufficient time. The assessment or monitoring plan elaborates and formalises the information on which the decision to accept the assessment or monitoring request is based (cf. Tool #13) and meets the quality-assurance requirements (cf. Tool #5).

The lead (appointed by the Steering Committee; cf. Tools #5 and #13) for the impact assessment or monitoring is responsible for the preparation of an assessment or monitoring plan. A typical structure of such a plan is:

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- Introduction impact assessment or monitoring
  - Description;
  - Organisations involved with their points of contact;
  - Reference documents (and their order of precedence);
  - Deliverables;
  - Special considerations (e.g. legally applicable (quality) aspects);
  - Contractual preconditions, e.g.
    - Type of contract;
    - Start date (kick-off), end date, and duration;
    - Obligations of customer.
- Technical execution impact assessment or monitoring
  - Organisation;
  - Work packages;
  - Project phasing
    - Milestones;
    - Planning of activities;
    - Alterations;
    - Customer acceptance;
    - Tracking and oversight management.
  - Capacity planning;
  - Archiving.
- Financial execution of impact assessment or monitoring
  - Cost information;
  - Payment conditions and payment schedule;
  - Contract termination.
- Quality assurance in impact assessment or monitoring
  - Quality assurance plan;
  - Requirements management;
  - Configuration management;
  - Risk management.

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- Communication in impact assessment or monitoring
  - Customer;
  - Partners;
  - Steering Committee;
  - Advisory Committee;
  - Pool of Excellence.

> *Regarding the use cases demonstrated in the Impact Monitor project, their assessment plan is a down-scoped version due to their main purpose: Demonstration use cases. These down-scoped assessment plans are laid down in the Impact Monitor deliverable D5.2 [22].*

Tool #16: Specifying methods for impact assessment or monitoring

Obviously, there is an obligation to apply the most sensible methodological approach for the impact assessment or monitoring, given the specificities of the European R&I in aviation at hand, the availability of models and data, and the requirement to carry out a proportionate analysis (cf. Tool #12). Whenever possible, significant (environmental, economic and societal) impacts should be assessed quantitatively. Only when a quantitative analysis is not possible, impacts are examined qualitatively.

The choice of the methodological approach to assess or monitor the environmental, economic and/or societal impact of the R&I under study will largely determine the (type of) models and data needed. This choice depends on the research questions to be answered, on the available results from Tool #14, and on the (level of detail of the) impacts to be quantified. Furthermore, a prerequisite for any impact assessment or monitoring that is evidence- and science-based is that the methods applied should be founded on well-established and -accepted instruments such as applicable EU Directives, international standards, and recommended and best practices as well as on the scientific state of the art. This could imply that various methods are applied to get the most comprehensive and robust impact assessment or monitoring.

As innovations in aviation can break new grounds and be disruptive, methods may not be fully matured, well-established or widely recognised; Methods may even be non-existent in those cases.

The following questions may guide in outlining the criteria for choosing the most appropriate analytical approach (some of which are already (partly) addressed in Tool #13):

- What are the most significant impacts? Which method can be applied?

  Not every method is equally suited to analyse the specific impacts of an R&I. Often a single measure needs various (inter-linked) methods (e.g. to analyse economic, social and environmental impacts).

- Which type of structuring is required?

  Which are the steps to implement the R&I?

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- What is the time horizon of the expected impacts of the R&I?

  The method should cover the full time horizon with significant effects.

- What kind of models and data is required to evaluate the R&I?

  Are the required models and data available and accessible? How sensitive is the method for (partially) missing models and data?

- How big is the amount of data required by the method? Which technical means (e.g. software and databases) are necessary to apply the method?

  Are the necessary technical means, knowledge, and hardware available to handle the models and the required amount of data? If not, can they be acquired?

- What kind of knowledge/expertise is required on the part of the Pool of Excellence?

  Is the required knowledge/expertise available in the Pool of Excellence and if not, can it be acquired (e.g. by expanding this Pool)?

- How many resources does the method need?

  Is the investment in a method proportional to the size of the research questions? Can the results or methods be used (again) for other (future) impact assessments or monitoring?

- How long does it take to apply the method?

  What is the estimated timeframe of the analysis and does it correspond with the objectives or deadlines of the R&I development process? What are the strategies if there is a lack of time?

- Has the method been used in previous impact assessments or monitoring?

  Exploiting the outcomes of Tool #14: Who might have experience in using the method and can provide advice?

Appendix D provides an initial list with examples of well-established methods to evaluate a few specific impact indicators.

> *Regarding the use cases demonstrated in the Impact Monitor project, their assessment plans describe the approach taken, as laid down in the Impact Monitor deliverable D5.2 [22].*

Tool #17: Specifying Baseline Scenario

With reference to Tool #3, the Baseline Scenario is a scenario that reflects the actual state of the (relevant part of the) air-transport system in a historic year. This scenario constitutes the basis for the Reference Scenario (cf. Tool #18) and the R&I Scenario (cf. Tool #19).

> *The Baseline Scenario for the use cases at airport and air-transport system level demonstrated in the Impact Monitor project (cf. [22]), is based on the state in 2019.*

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Tool #18: Specifying Reference Scenario

With reference to Tool #3, the Reference Scenario is a future projection of the (relevant part of the) air-transport system in the future year to be considered for the impact assessment or monitoring. It is the scenario against which the impacts of the European aviation R&I under study are assessed or monitored. For assessments or monitoring at aircraft level, the Baseline Scenario and Reference Scenario could be identical. Obviously, the Reference Scenario should be defined such that it allows the assessment or monitoring of the environmental, economic and societal impact of the R&I under study. Also, it should consider a time horizon appropriate to the impact assessment or monitoring.

The future projection is a 'no-change' or 'business-as-usual' scenario for the future year(s) of the R&I to be assessed or monitored, starting from the Baseline Scenario. It includes all expected (and relevant) autonomous economic, demographical and technological developments (including foresight aspects such as megatrends) up to that year, but without the R&I under investigation. In this way the assessment or monitoring of the R&I is robust and future-proof. Moreover, it can help anticipate trends, risks, emerging issues, and their potential implications and opportunities to draw useful insights for strategic planning, policymaking and preparedness.

Practical steps in the identification of assumptions for a Reference Scenario are:

1. Identification and quantification

   An appropriate time horizon should be determined; for instance, associated with an important year for which goals have been set (e.g. 2050 in light of the EU's Green Deal). For this time horizon, the Reference Scenario should then reflect all relevant policies and measures that are assumed to be in force or implemented until the time horizon, expected socio-economic developments and trends (such as gross domestic product (GDP) and demographical developments), and important technological and societal developments (such as emerging aviation and mobility technologies, and mobility needs). Since impact assessments and monitoring are often model-based, the assumptions should correspond basically to those of the underlying models and therefore, cover all relevant assumptions underpinning the models themselves, their application, and their implementation. With reference to Tool #4, it is important to be transparent with the limitations and error margins in quantifying these assumptions.

2. Validity and consistency checks

   The set of assumptions for a Reference Scenario should not have logical or factual contradictions within. A Reference Scenario is context-dependent and there may be differences across Reference Scenarios for various reasons: Same models but different R&I, same area of analysis using similar models, same impact assessment/monitoring but with different models with shared assumptions, different impact assessment/monitoring with different models with overlapping assumptions, and same models with different points in time.

   Contradictions between assumptions in Reference Scenarios can undermine the credibility of impact assessments or monitoring, and if they occur, they should be explicitly recognised

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and fully justified. Although avoiding contradictions can be regarded as a principle of good governance, consistency should be strived for to facilitate comparability of impact assessments and monitoring across time and R&I domain. Hence, wherever possible, standardised scenarios could be developed and used for various R&I's.

3. Documentation

   In line with Tool #4, all assumptions should be documented in the impact assessment or monitoring report (cf. Tool #26).

The Reference Scenario should take account of:

- Megatrends, which are long-term global driving forces that are observable in the present and are likely to continue to have a significant influence for a few decades, and which have the potential to lead to large- and broad-scale transformations. EC's Megatrends Hub [10] (and its tool [11]) might be of help.
- Future (long-term) scenarios, which are plausible consistent pictures of the future and may consider one or more megatrends. Such scenarios could allow:
  - Considering key uncertainties by understanding viable alternative future developments and the role and interests of different stakeholders therein;
  - Anticipating changes in autonomous economic, demographical and technological developments in the medium to long term.

The findings of megatrends and future (long-term) scenarios should then be considered in the impact assessment or monitoring by:

- Identifying the relevant megatrends and scenarios to be used, in order to ensure a systematic, future-oriented analysis of drivers and their evolution;
- Analysing the impact (i.e. long-term implications) of relevant megatrends and scenarios to the implementation of the R&I under study, in order to understand their effect.

Finally, it is acknowledged that various organisations regularly develop outlooks or scenarios to forecast aviation (e.g. to forecast fleet and air traffic, or to forecast major infrastructural modifications), such as EC, EUROCONTROL, EASA, UN/ICAO, individual airports (and their representative organisations such as ACI), airlines (and their representative organisations such as IATA) and aircraft-manufacturing industry. Their methodologies, scenarios and forecasts can also help in specifying the Reference Scenario.

> *The Reference Scenario for the use cases (in particular at airport and air-transport system level) demonstrated in the Impact Monitor project (cf. [22]), is a projection of the state in 2050; of course, without any of the R&I assessed. This scenario is taken from the Second Global Assessment 2024 of Clean Sky 2 TE (cf. [3]).*

Tool #19: Specifying R&I Scenario

With reference to Tool #3, the R&I Scenario is the Reference Scenario in which the European aviation R&I under study is implemented. Its impacts are assessed or monitored against those

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of the Reference Scenario. Clearly, the R&I Scenario should take account of when and how the R&I can realistically be implemented in the medium to long term. That is, it should consider key uncertainties by understanding viable alternative future developments and the role and interests of different stakeholders in the implementation of the R&I and how these may affect autonomous economic, demographical and technological developments in the medium to long term.

> *The R&I Scenario for the use cases (in particular at airport and air-transport system level) demonstrated in the Impact Monitor project (cf. [22]), is a projection of the state in 2050 (i.e. the Reference Scenario), but in this case of course with the R&I implemented.*

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5. TOOLBOX: ASSESSMENT AND MONITORING – EXECUTION

Once the impact-assessment or monitoring is set up, the next step is the execution of the assessment or monitoring in accordance with its plan from Tool #15. A natural order of application of the tools associated with the execution of the impact assessment or monitoring (as listed below) is illustrated in Figure 5.

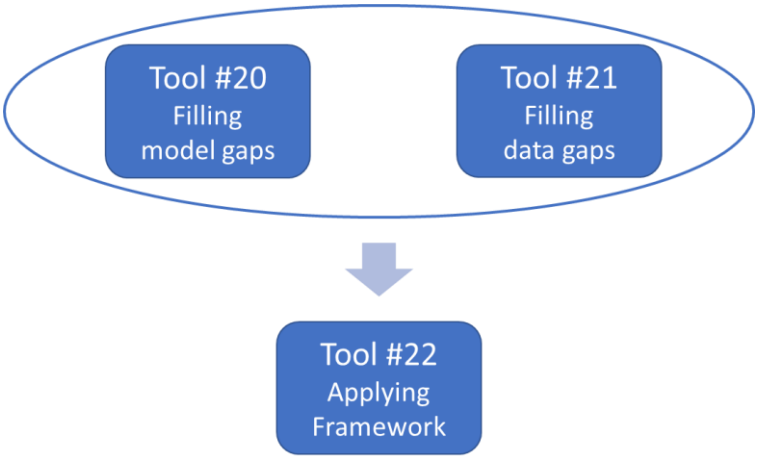

Figure 5. Impact Monitor-assessment and -monitoring Execution – General Schema

Tool #20: Modelling for impact assessment or monitoring

In case of any model gap (cf. Tools #13, #14 and #16), this gap needs to be filled to enable the impact assessment or monitoring of the European aviation R&I under study. It includes:

- Identification of approaches and methods;
- Selection of approach and method;
- Implementation of approach and method.

The choice of the analytical approach and method depends largely on the underlying research questions to be answered (cf. Tools #6 and #7) as well as on the already available evidence (cf. Tools #14 and #16). A combination of quantitative and qualitative methods may be used to get the most comprehensive picture. It is noted that it may be unclear what methodological approach best suits evidence needs.

Filling model gaps should be consistent with the level of detail and proportionality required, be compliant with relevant Directives, international (scientific) standards and recommended or best practices, be founded on similar underlying assumptions and principles as for other models used, be built in an appropriate language, and be integrated into the Impact Monitor Framework.

The modelling process and approach should be properly documented for reasons of transparency and reproducibility. It is important to carefully document what was possible, but also what was not possible.

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> *Regarding the use cases demonstrated in the Impact Monitor project (cf. [22]), the modelling was limited to the modelling required to meet their demonstration. That is, the modelling of SAF fuelled novel aircraft concepts (UC1), of continuous descent operations (UC2), and of different policies for the uptake of SAF (UC3). For this purpose, all models were already available to the Impact Monitor consortium.*

Tool #21: Collecting data for impact assessment or monitoring

In case of any data gap (cf. Tools #13, #14 and #16), this gap needs to be filled to enable the impact assessment or monitoring of the European aviation R&I under study. The choice of the methodological approach determines largely the type of data that is needed. The main steps in this data collection are:

- Identify data sources;
- Select data source (although multiple data sources could be used for cross-validation);
- Apply data in data structure of and/or models in Impact Monitor Framework.

With reference to Tool #4, there should be a preference for data sources that comply with the principle of FAIR. Further, for reasons of transparency and reproducibility, the data collection process should be properly documented. This documentation should include a reporting on what data were possible and not possible to collect.

Appendix B provides an initial list with main data sources commonly used in modelling in aviation.

> *Regarding the use cases demonstrated in the Impact Monitor project (cf. [22]), data collection was limited to data required to meet their demonstration. These data were readily available to the Impact Monitor consortium.*

Tool #22: Applying Framework for impact assessment or monitoring

The Impact Monitor Framework constitutes the environment to carry out all calculations for the impact assessment or monitoring of the European aviation R&I under study. It integrates all models with their data sources included in the Model Catalogue and is possibly extended with additional models and data sources (cf. Tools #20 and #21) for the impact assessment or monitoring at hand (e.g. by selecting additional models and data sources, enhancing models already included, or developing new models to fill any model gap) together with the Framework's central data repository.

To carry out these calculations through the Impact Monitor Framework, a dedicated workflow should be defined and implemented. After that, the workflow can be activated and the calculations subsequently performed.

The outcomes of Tool #22 are the raw, quantified evidence for the impact assessment or monitoring to be used in the next and final step (cf. Section 6).

> *Each use case demonstrated in the Impact Monitor project (cf. [22]) carries out its calculations through the Impact Monitor Framework, after integrating the models, connecting the models with the (updated) central data repository, and implementing the workflows. See the Impact Monitor deliverable D5.3 [23].*

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6. TOOLBOX: ASSESSMENT AND MONITORING – ANALYSIS

With the evidence collected in the previous step, the final step in the impact assessment or monitoring is the analysis, interpretation, presentation and reporting of the assessment or monitoring. In general, the order in which the associated tools (as listed below) are applied, is the order in which they are presented (see also Figure 6).

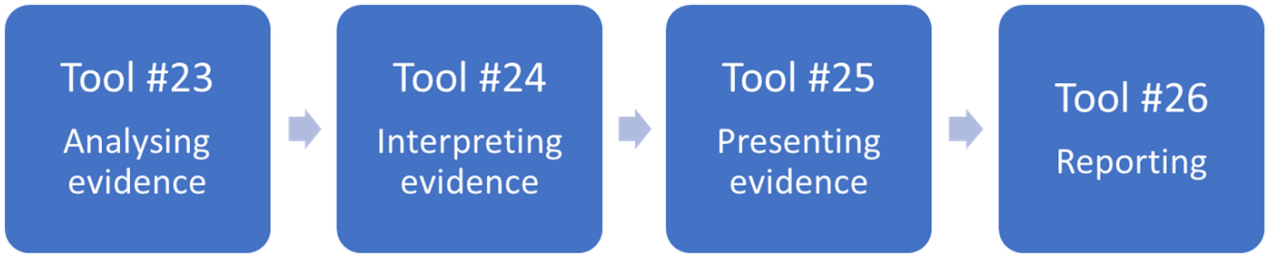

Figure 6. Impact Monitor-assessment and -monitoring Analysis – General Schema

> *As the implementation of use cases in the Impact Monitor project (cf. [22]) is merely for demonstration purposes of the Impact Monitor Framework, the tools in Section 6 are not applied in the project. However, the TE report in Clean Sky 2 on the Second Global Assessment [3] addresses various of the tools listed below, and (obviously) in particular elements mentioned in Tool #26.*

Tool #23: Analysing evidence for impact assessment or monitoring

Critical, impartial and transparent assessment and validation of the collected evidence ensure that this evidence is robust and reliable for the impact assessment or monitoring of the European aviation R&I at hand. Peer-review is a common method of quality assurance increasing credibility.

- Cost-benefit analysis and multi-criteria analysis

  In various cases an impact assessment or monitoring involves the consideration of alternative R&I's. The traditional and widespread approaches for comparing alternatives are cost-benefit analysis and multi-criteria analysis.

  Cost-benefit analysis is based on welfare economic theory, where impacts are made comparable in monetary terms using the notion of willingness to pay. These monetary impacts are subsequently aggregated into a final indicator. Thanks to the theoretical foundation, the outcomes of a cost-benefit analysis are clearly interpretable and easy to use.

  Multi-criteria analysis, on the other hand, has a less thorough theoretical foundation. It allows to incorporate a broader range of impacts for which no clear monetary evaluation is available but are viewed as important by the stakeholders. For these impacts, weighting methods can be used such as scoring or ranking. A multi-criteria matrix can then be used to present in a structured way the information on various 'criterion scores'. These scores can evaluate impacts by using both quantitative and qualitative information.

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- Uncertainty and sensitivity analysis

  Uncertainty analysis aims at quantifying uncertainties in model results due to uncertain assumptions/inputs. Sensitivity analysis allows identifying the uncertain assumptions mostly responsible for uncertainty in model results.

  Uncertainty and sensitivity analyses support evidence reporting in terms of ranges rather than a single value, herewith enriching the analysis and impact assessment or monitoring.

With reference to Tool #11, changes in the indicators selected for the impact assessment or monitoring should be attributable to the R&I under study. Analysing causal effects could help in identifying the effect of an R&I on the outcomes of interest. (Although related, causality should not be confused with correlation.)

In analysing impacts, interactive applications (such as the Impact Monitor Dashboard Application [20]) can provide additional support to for instance, analysing evidence and conducting what-if and trade-off studies through the use of visualisation techniques and methods.

Tool #24: Interpreting evidence for impact assessment or monitoring

Interpreting evidence collected is transforming evidence into knowledge, which allows for drawing conclusions. When choosing experts for interpreting evidence, the preferred option is to include representatives from various disciplines to avoid “tunnel vision”.

Aspects for consideration when interpreting evidence are:

- Check whether results support the conclusions

  When a first outline of conclusions has been established, it is a good moment to take a step back and think: Are these conclusions supported by the aggregated evidence collected and analysed in Tool #23? In particular, it should be verified whether the evidence is strong enough to underpin the conclusions. If some of the evidence does not align with expectations, or if different pieces cannot be reconciled, it is preferable to state all the evidence anyway, identifying the possible lack of uniformity or conclusiveness.

- Integrate insights from all types of evidence

  Different types and sources of evidence should be distinguished and treated according to their credibility, relevance and ability to provide useful insights. Gathered data may be incomplete and information may be biased, or suffer from other imperfections. Some evidence may lack scientific robustness but may still carry relevance because of the richness of the insights it offers. Both “mainstream” and “divergent” views should be considered and reported.

- Make interpretation explicit

  Interpretation of evidence should be as transparent as possible, so that all the choices, assumptions, weights, and value judgements are clearly explained and understandable.

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Tool #25: Presenting evidence for impact assessment or monitoring

A good presentation of evidence and its conclusions facilitates good communication and allows making well-informed decisions. Considerations in presenting evidence are:

- Being transparent on limitations

  Transparency about the underlying judgements and the limits of the evidence used, including availability and robustness, is key. It is important to communicate what conclusions can and cannot be drawn at this stage. Transparency is also needed on the assumptions upon which the analysis is based.

- Thinking about the audience and tailoring the language accordingly

  The evidence used should be clearly presented and cited by providing all relevant source details. Hence, the evidence should be presented in a manner that is easily understood by diverse audiences. Consequently, bureaucratic or too technical language should be avoided and necessary specialist terms should be explained[12].

  To be transparent about the evidence underpinning the conclusions does not mean simply to include more quantitative and qualitative data in the report as this may be counterproductive. Technical details may be provided in annexes and supporting studies.

- Ensuring that the key evidence is available and remains traceable

  Especially when studies supporting the analysis provide technical details, these documents should be stored in stable and permanent databases or repositories, where they are equipped with persistent identifiers. The key evidence should be cited by providing all relevant details to allow its findability, including persistent identifiers and/or permalinks to ensure functioning hyperlinks.

  Supporting evidence – including underlying data if these are open – should be made available.

> *Regarding the use cases demonstrated in the Impact Monitor project (cf. [22]), their results are presented through an interactive dashboard developed in the project (cf. [20]).*

Tool #26: Format of impact assessment or monitoring report

The impact-assessment or -monitoring report should present the key information associated with the assessment or monitoring. It should be:

- Self-standing document

  The report should clearly present the assessment or monitoring, the underlying assumptions and choices made, the data (sources) and models used, and the results with interpretations,

[12] Various guiding materials can be exploited, such as EC's guide 'How to write clearly': `op.europa.eu/en/publication-detail/-/publication/bb87884e-4cb6-4985-b796-70784ee181ce/language-en`

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analyses and/or recommendations towards the target stakeholders (or stakeholder categories). Tables, graphs and figures should obviously be self-explanatory.

- Written with involved, served and impacted stakeholders in mind

  As society is often impacted, the report should therefore in general be written in a non-technical language with non-expert readers in mind; technical details can be presented in annexes to the report.

The impact-assessment or -monitoring report should at least contain:

- Title page with (main) authors, reviewers, approver(s), date of issue, and version number;
- Page with change history of report;
- Executive summary, which serves as a communication tool to present the report in a quick and reader-friendly way and summarises the main elements of the analysis in a visually attractive format and plain (English UK) language.
- Chapter on context and background

  The introductory chapter covers the scope, context and background of the impact assessment or monitoring (based on Tool #6) and describes the organisation of the report.
- Chapter on European R&I in aviation assessed or monitored

  This chapter covers the objective of the impact assessment or monitoring, especially by summarising the outcomes of Tools #7, #8, #9, #10, and #11; such as addressing topics:

  - What R&I has been assessed or monitored?
  - What problem does this R&I aim to (help to) alleviate?
  - What does this R&I aim to achieve?
  - What stakeholders or stakeholder categories are (or could be) involved in, served by and/or impacted by this R&I, and how?
  - What assessment levels are to be considered (i.e. aircraft, airport and/or air-transport system level) for this R&I?
  - What is the year for the Baseline Scenario and what is (are) the year(s) for the Reference Scenario(s) and the R&I Scenario(s) for this R&I?
  - What key-performance indicators are to be quantified for this R&I and how are these linked with (or contribute to) SDGs?
  - What EU Directives and international standards are applicable for assessing or monitoring this R&I?
- Chapter on impact-assessment or -monitoring process

  This chapter covers the aspects of the impact-assessment or -monitoring process, including:

  - Evidence mapping (e.g. through Tool #14);

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  - Methodological approach (e.g. through Tools #16, #17, #18 and #19), including:
    - Relevant EU Directives, international (scientific) standards and best practices;
    - Underlying assumptions;
    - Alternative approaches and reasoning for selecting this approach.
  - Models used and developed as well as data (sources) used and collected (e.g. through Tools #16, #20 and #21);
  - Chain of models (e.g. through Tool #22);
  - If applicable, why some evidence may not be available and how this affect the assessment or monitoring.
- Chapter on impact-assessment or -monitoring results (e.g. through Tools #22 and #25)

  This chapter covers the evidence collected through the approach applied in the preceding chapter and presents it (as much as possible and suited) in tables, graphs and figures that are self-explanatory. The evidence should be differentiated between the various stakeholders (or stakeholder categories) concerned.
- Chapter on analysis, interpretation and recommendation (e.g. through Tools #23, #24 & #25)

  This chapter describes how the evidence collected is analysed and interpreted as well as the outcomes of this analysis and interpretation. Moreover, it provides recommendations (if any) on the impact assessment or monitoring itself, on opportunities for further research, and on the R&I under study.
- List of references and list of abbreviations and acronyms used in the report

  This document contains a comprehensive list of references used in the assessment or monitoring, and a list of abbreviations and acronyms used in the report.

To limit the number of pages of the core of the report, details should be shifted to annexes.

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7. CONCLUSION

The present document presents the Impact Monitor Toolbox, and explains what conducting holistic impact assessments and monitoring entails while being targeted, effective, easy to comply with, and with the least burden possible. It provides a systematic approach of the complete cycle of performing impact assessments and monitoring of European aviation R&I. In order words, it is a way of working by providing guidance, tips, and best practice.

The Impact Monitor Toolbox is especially inspired by the EC's Better Regulation Guidelines & Toolbox (cf. [8] & [9]) and, while noting Better Regulation deals with creating legislation, could be regarded to a large extent as a tailored and paraphrased version thereof. However, it also capitalises on work for instance, in ECAC/ANCAT-MITG and in EU projects TEAM_Play [28], Technology Evaluator in Clean Sky 1 & 2 [2] , and SESAR [27].

The Impact Monitor Toolbox comprises 26 tools, while noting it is not expected to apply each individual tool to any impact assessment or monitoring, but to use the toolbox selectively and with common sense:

- Assessment-process flow, Basics and Organisation
  - Tool #1: What is impact assessment;
  - Tool #2: What is impact monitoring;
  - Tool #3: Fundamental of impact assessment or monitoring;
  - Tool #4: Principles in impact assessment or monitoring;
  - Tool #5: Organisational bodies in impact assessment or monitoring.
- Assessment and monitoring – Specification
  - Tool #6: Understanding impact-assessment or -monitoring request;
  - Tool #7: Specifying impact assessment or monitoring;
  - Tool #8: Identifying stakeholders of impact assessment or monitoring;
  - Tool #9: Identifying impacts for impact assessment or monitoring;
  - Tool #10: Linking with SDGs in impact assessment or monitoring;
  - Tool #11: Quantifying impact in impact assessment or monitoring;
  - Tool #12: Proportionality to impact assessment or monitoring;
  - Tool #13: Decision on conducting impact assessment or monitoring;
  - Tool #14: Evidence mapping for impact assessment or monitoring.
- Assessment and monitoring – Set-up
  - Tool #15: Planning impact assessment or monitoring;
  - Tool #16: Specifying methods for impact assessment or monitoring;

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  - Tool #17: Specifying Baseline Scenario;
  - Tool #18: Specifying Reference Scenario;
  - Tool #19: Specifying R&I Scenario.
- Assessment and monitoring – Execution
  - Tool #20: Modelling for impact assessment or monitoring;
  - Tool #21: Collecting data for impact assessment or monitoring;
  - Tool #22: Applying Framework for impact assessment or monitoring.
- Assessment and monitoring – Analysis
  - Tool #23: Analysing evidence for impact assessment or monitoring;
  - Tool #24: Interpreting evidence for impact assessment or monitoring;
  - Tool #25: Presenting evidence for impact assessment or monitoring;
  - Tool #26: Format of impact assessment or monitoring report.

The Impact Monitor Toolbox is a living document. For instance, it shall be applied in the follow-up project "Impact Monitor 2" [24] and, based on this application and on newly emerging needs and requirements, further fine-tuned, enhanced and updated.

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[4] ECAC (2016), ECAC.CEAC Doc 29, Report on Standard Method of Computing Noise Contours around Civil Airports, Volume 1: Applications Guide, 4th Edition, as endorsed by DGCA/147 on 7 December 2016.

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APPENDIX A – MAPPING IMPACT MONITOR TOOLBOX ONTO BETTER REGULATION TOOLBOX

Table A.1 globally maps the tools from the Impact Monitor Toolbox onto (aspects of) the ones from the EC's Better Regulation Toolbox. It is to be noted that the context of Better Regulation is creating legislation and therefore, differs from the context of the Impact Monitor project.

Table A.1. Impact Monitor Toolbox mapped onto Better Regulation Toolbox

Impact Monitor Toolbox	Better Regulation Toolbox
Tool #1	Tools #4 and #7
Tool #2	Tools #4 and #43
Tool #3	Tool #4
Tool #4	Tool #1
Tool #5	Tools #3 and #61
Tool #6	Tools #4 and #15
Tool #7	Tool #4
Tool #8	Tool #52
Tool #9	Tool #18
Tool #10	Tools #18 and #19
Tool #11	Tools #21, #22, #24, #25, #27, #30, #31, #32, #33, #34, #36, #43, and #56
Tool #12	Tool #12
Tool #13	-
Tool #14	Tool #4
Tool #15	Tool #8
Tool #16	Tools #18, #21, #22, #24, #25, #27, #30, #31, #32, #33, #34, #36, #57, #58, #59, #60, and #67
Tool #17	-
Tool #18	Tools #4, #16, #20, and #60
Tool #19	-
Tool #20	Tool #4
Tool #21	Tools #4, #43, #61, and #67

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Tool #22	-
Tool #23	Tools #4, #62, #63, and #65
Tool #24	Tool #4
Tool #25	Tools #4 and #55
Tool #26	Tool #11

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APPENDIX B – CANDIDATE MODELS AND DATA SOURCES FOR MODEL CATALOGUE

An initial list of candidate models for the first version of the Impact Monitor Model Catalogue is established in Appendices B.1-B.3, by considering the extent to which a model:

- Supports at least one aspect in each of the three assessment levels;
- Is state of the art;
- Is sound from a scientific point of view;
- Is transparent from the perspective of stakeholders;
- Is of high quality;
- Is documented.

Further, Appendix B.4 provides an initial list of a few candidate data sources.

B.1 Models in MIDAS

The Modelling Inventory and Knowledge Management System of the European Commission (MIDAS) is a Commission-wide knowledge management system for modelling, enabling enhanced transparency and traceability of models in use for EC policy making; See for an introduction [25].

MIDAS organises the models used per DG[13]. A few examples of models from DG-CLIMA, DG-ENV, DG-MOVE and DG-TAXUD that might potentially be relevant for an impact assessment or monitoring of European aviation R&I, are:

- AERO-MS: Aviation Emissions and Evaluation of Reduction Options Modelling System;
- AIM: Aviation Integrated Model;
- ASTRA: Assessment of Transport Strategies;
- E3ME: Energy - Environment - Economy Model for Europe;
- EPIC: Environmental Policy Integrated Climate;
- GAINS: Greenhouse Gas and Air Pollution Interactions and Synergies Model;
- General Equilibrium Model - Economy, Energy, Environment;
- JRC-EU-TIMES: JRC TIMES energy system model for the EU;
- NEAC: European Transport Forecast Model;
- PRIMES: Price-induced Market Equilibrium System;

[13] web.jrc.ec.europa.eu/policy-model-inventory/explore/

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- PRIMES-TREMOVE: Transport Model;
- TRUST: Transport European Simulation Tool;
- Vivid EU ETS model: European Union Emissions Trading System mode.

B.2 Models in Impact Monitor consortium

Within the Impact Monitor consortium, a wide variety of models is available and has been successfully applied to impact assessment or monitoring. To name a few:

- Aircraft level
  - AECCI[14]: Aircraft Emission and Contrails for Climate Impact Tool (ONERA);
  - AMC: Aircraft mission calculator (DLR);
  - DYNAMO[14]: 4D aircraft trajectories (UPC);
  - GSP: Generic gas turbine simulation tool (NLR);
  - Holistic sustainability assessment tool (University of Patras);
  - openAD: Aircraft Design (DLR);
  - SUAVE: Impact of sustainable aviation fuel on aircraft level (University of Stuttgart);
  - TURBOMATCH: Aircraft engine configuration model (Cranfield University).
- Airport level
  - LEAS-iT: Emissions calculations (NLR);
  - SCBA: Social Cost-Benefit Analysis tool (TML);
  - STACKS: Local air quality model (NLR);
  - TRIPAC: Third-party Risk Analysis Package (NLR);
  - Tuna: Noise calculations (NLR).
- Air-transport system level
  - Scheduler[15]: Flight schedules (DLR);
  - AirClim: Climate impact assessment of aircraft emissions (DLR);
  - FORMO: Passenger and fleet forecast model (DLR);
  - FATS: Aviation traffic scenarios (DLR);
  - TRAFUMA: Economic analysis of transport fuel policies (TML).

[14] Model is in principle suited for impact assessments or monitoring at airport and air-transport system level as well
[15] Model can also be applied to impact assessments or monitoring at airport level

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B.3 Models outside Impact Monitor consortium

It goes without saying that outside the Impact Monitor consortium there is a vast number of models that have been successfully applied to impact assessments or monitoring. Think for instance of models used in TEAM_Play and listed in the ECAC / MITG model inventory, such as:

- AAT: Aircraft Assignment Tool (EUROCONTROL)

  Forecast of aircraft-type usage.
- ADMS-Airport: Atmospheric Dispersion Modelling System for Airports (CERC)

  Local air-quality emissions and concentrations at and around airports.
- AEDT: Aviation Environmental Design Tool (FAA)

  Aircraft performance to estimate fuel consumption, emissions, noise, and air quality.
- AEM: Advanced Emission Model (EUROCONTROL)

  Estimation of aircraft's fuel burn and emissions.
- AERO-MS: Aviation Emissions and Evaluation of Reduction Options Modelling System (EASA)

  Examination of environmental and economic impacts of policies (technological, operational and market-based measures) intended to reduce greenhouse-gas emissions from international and domestic aviation.
- AIM: Aviation Integrated Model (University College of London)

  Simulation of air-transport system, environmental, and economic impacts of policy measures.
- AirTOp: Airport and airspace simulation software (Transoft Solutions)

  Airport and airspace simulation to model, simulate, and visualise airport and air-traffic operations in fast-time.
- ANCON: Aircraft Noise Contour (UK-CAA)

  Impact of aircraft noise on population living near airports.
- FAST: Future Civil Aviation Scenario Software Tool (MMU)

  Aviation emissions inventory and scenario modelling platform.
- GAMMA: Generator of Aircraft and Motors required to Manage Air Transport Demand (ENAC)

  Forecast of world-wide aircraft fleet and usage.
- IMPACT (EUROCONTROL)

  Environmental-impact assessments (noise and emissions using AEM and STAPES).
- LASPORT: Lagrangian Simulation of Aerosol-Transport for Airports (Janicke Consulting)

  Local air-quality emissions and concentrations at and around airports.

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- LinClim: Linear Climate response model (MMU)

  Forecast of global radiative forcing and temperature responses from aviation scenarios.
- (Open-)ALAQS: Airport Local Air Quality Studies Modelling Tool (EUROCONTROL)

  Local air-quality emissions and dispersion at and around airports.
- STAPES: System for Airport Noise Exposure Studies (EUROCONTROL)

  Noise exposure aggregated for major European airports.

B.4 Data sources

For the specification of Reference and R&I scenarios and the quantification of impacts of R&I, various data types are needed, such as data on air transport (demand and supply), aircraft performance, airport data, and cost and revenue data. Examples of sources for such data are:

- Air transport data
  - COD (Common Operations Database) / WISDOM (World Interconnected Sources Database of Operational Movements);
  - Cirium;
  - Flightradar24;
  - EUROCONTROL (EUROSTAT and STATFOR);
  - ICAO Data+ series: Module with air carrier traffic;
  - ICAO TFS (Traffic by Flight Stage);
  - OAG (Official Airline Guide);
  - OpenSky;
  - Sabre: Passenger traffic.
- Aircraft specifications and performance
  - Aircraft Noise and Performance (ANP);
  - BADA (Base of Aircraft Data);
  - Database of Emissions Indices;
  - ICAO's Aircraft Engine Emissions Databank;
  - PIANO;
  - PRISME.
- Airport data
  - Aeronautical Information Publications (AIPs);
  - Boeing: Airport Noise and Emissions Regulations;

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  - STAPES: Airport Database;
  - WebDab: Emissions Database EMEP (Co-operative programme for monitoring and evaluation of long-range transmission of air pollutants in Europe).
- Others
  - EEA and JRC: Population density database;
  - Form 41 US P-52: Route group average yields;
  - Global Insight: Economics forecast;
  - IATA economics briefing;
  - IEA: Oil resources and oil fuel prices;
  - ICAO: Data on air carrier finances, air carrier personnel, air carrier fleet, regional difference, and landing and route charges.

Finally, the EC also collects and provides data. Well-known global examples are `data.europa.eu`, EUROSTAT[16], JRC data catalogue[17], and OpenAIRE[18]. The EC's Better Regulation Toolbox [9] gives an extensive account of data sources relevant to its application.

[16] `ec.europa.eu/eurostat`
[17] `data.jrc.ec.europa.eu/`
[18] `www.openaire.eu/`

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APPENDIX C – INITIAL LIST OF KEY-PERFORMANCE INDICATORS

An initial list of candidate key-performance indicators (KPIs) for impact assessments or monitoring of European R&I in aviation is established by considering:

- Impact assessments of innovations (or classes of innovations) in previous, running and anticipated EU aviation R&I programmes/projects

  European aviation R&I programmes/projects considered cover programmes/projects on aircraft technology and concepts (e.g. TE in Clean Sky 1 & 2 and Impact Monitor in Clean Aviation), on ATM, operations and infrastructure (e.g. SESAR, SESAR 2020, SESAR 3, and ClimOP), on sustainable aviation fuels and alternative propulsion (e.g. Clean Hydrogen and Clean Aviation), and on policies and regulations (e.g. Green Deal, Fit-for-55, European Climate Law, Renewable Energy Directive, Emissions Trading System, Destination 2050, and UN Sustainability Development Goals).

- Impact models available or known to consortium

  Models considered cover the full range of models for assessments and monitoring at all three levels, i.e. at aircraft, airport and air-transport system level, as well as a wide variety of key-performance areas (e.g. climate, emissions & air quality, safety, quality of life, economy, efficiency, predictability, capacity, effectiveness, and coherence). Appendix B provides an initial list of candidate models for the Impact Monitor Model Catalogue.

- Impact-assessment methodologies in EU Directives, international standards, and best practices

  Methodologies considered cover the full range of assessment levels: aircraft level (e.g. TE in Clean Sky 1 & 2, criteria in EASA aircraft certification, and ICAO Annex 16), airport level (e.g. Directive 2002/49/EC, Regulation 598/2014, ICAO Doc 9889, SESAR 2020 PJ19, EUROSTAT Quality of Life, ICAO Key Performance Areas air navigation, and TE in Clean Sky 1 & 2), and air-transport system level (e.g. ICAO Key Performance Areas air navigation, TE in Clean Sky 1 & 2, European Aviation Environmental Report 2025, ICAO Environmental Report 2022, ICAO's Economic analysis and forecasts, and ATAG Study on economic & social benefits of air transport).

Noting it will be subject to continuous updates, the initial list of key-performance indicators for impact assessments or monitoring of European R&I in aviation is presented below. This list merely serves as a list of candidate indicators and is not (and cannot be) exhaustive.

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KPA	KPI – Aircraft level	KPI – Airport level	KPI – Air-transport system level
Climate	• CO_2 equivalents [tonnes] • Non-CO_2 emissions with climate impact [tonnes]	• CO_2 equivalents [tonnes]	• CO_2 equivalents [tonnes] • Non-CO_2 emissions with climate impact [tonnes] • Contrail formation • Average temperature response • Global warming potential • Radiative forcing • Aviation fuel mix • CO_2 offsets
Emissions & air quality	• Species [tonnes, tonnes/RPK]	• Species below 3,000 ft [tonnes] • 4D emissions inventory • Species concentration below 3,000 ft	• Species [tonnes] • Species per passenger [tonnes/passenger] • Species [tonnes/km, tonnes/nm] • 4D emissions inventory • Feedstock / energy consumption for SAF
Noise	• SEL • LA_{max} • Noise in certification points • Noise energy	• L_{den} • L_{night} • LA_{max} • Population impacted • Surface area contours • NA_X	• Noise energy • Population impacted
Safety	• Accident probability	• Individual risk • Societal risk • Houses/population in individual risk contours	• Number of accidents • Public safety
Quality of life		• Health • Annoyance • Disturbance	• Welfare • Employment • Jobs created in aviation sector • External cost • GDP per capita • Public health • Mobility • Multimodality • Connectivity • Working conditions • Income • Circular economy • Innovation • Globalisation • Governance • Education and training • Equity

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KPA	KPI – Aircraft level	KPI – Airport level	KPI – Air-transport system level
Economy	• Fuel consumption [tonnes, litres, per RPK] • Utilisation / load factor • Cost - Per flight - Purchase - Operation - Maintenance - Life-cycle - RPK	• Network • Number of direct/indirect connections • Operating cost • Investment • Landing charges	• Cost / revenue per stakeholder • Consumer and producer surplus • External cost • GDP and GVA • Air traffic demand and unaccommodated air traffic • Fuel demand and consumption (including share of different fuel types) • Flights • Fleet • Movements • Flight schedules • Number of direct/indirect connections • Passenger and freight volume • ASK and RPK • Prices • Import SAF / energy • Taxes • Competitiveness • Circular economy • Innovation • Tourism
Efficiency	• Flight efficiency • Flight time • Performance • Average delay • Load factor • Fuel intensity [MJ]	• 4D trajectory • Delay • Capacity • Throughput (e.g. runway, taxiway) • Punctuality	• Cost / benefit (or cost effectiveness) • Capacity • Throughput • Workload • Flights per ATCO- Hour on duty • Average departure delay per flight • Gate-to-gate flight time
Predictability	• Flight time • Performance • Punctuality (scheduling) • Tugging	• 4D trajectory • Delay • Capacity • Throughput • Punctuality	• Cost / benefit (or cost effectiveness) • Capacity • Throughput • Workload • Flights per ATCO- Hour on duty • Average departure delay per flight • Gate-to-gate flight time

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KPA	KPI – Aircraft level	KPI – Airport level	KPI – Air-transport system level
Capacity	• Turnaround • Taxi-routing • Tugging	• Airport airside capacity • Airport terminal • Peak Runway Throughput • Extended Departure management	• Free Route and Flexible Use of Airspace • Network utilisation • 4D trajectory • En-route throughput per unit time. • TMA throughput per unit time.
Effectiveness	• Contribution to goals/targets [percentage of success level]	• Contribution to goals/targets [percentage of success level]	• Contribution to goals/targets [percentage of success level]
Coherence			• With other EC objectives, rules, initiatives

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APPENDIX D – EXAMPLES OF METHODS TO QUANTIFY KEY-PERFORMANCE INDICATORS

The following subsections provide only a few examples for quantifying various KPIs listed in Appendix C.

D.1 Environmental and climate impact

Environmental impacts are changes in the state of the environment due to anthropogenic activities, which may also have a health impact (cf. Appendix D.2). In line with EU Regulation No. 2020/852, an impact assessment or monitoring includes positive and negative environmental impacts of the R&I under consideration. Examples of methods to quantify several environmental impacts listed in Appendix C[19], are:

- Emissions and air quality: ICAO Doc 9889 (e.g. Boeing fuel flow method 2 for emissions and Gaussian formulation of Lagrangian modelling or Lagrangian particle modelling) [17];
- Climate: CLAIM project [1] (e.g. for global warming potential and average temperature response);
- Noise
  - Aircraft level: ICAO Annex 16 (e.g. noise in certification points) [16];
  - Airport level: Directive 2002/49/EC, EU Directive 2015/996, and ECAC Doc 29 methodology [4]-[6];
  - Air-transport system level (proxy for noise energy): EASA, EEA and EUROCONTROL [7].
- Safety
  - Third-part risk: Law of the Netherlands [15];
  - Mid-air collisions en-route / in TMA / at runway / at taxiway: SESAR Performance Framework [26];
  - Wake-related accidents: SESAR Performance Framework [26];

In the context of innovation in R&I policies and as mentioned in the EC's Better Regulation Toolbox [9], the DPSIR framework (Drivers, Pressures, State, Impact and Response model of intervention) has been widely adopted by EEA. It is a causal framework for describing the interactions between society and environment.

D.2 Health impact

Health is a fundamental value, and improving health of people is improving their quality of life. If possible, health impacts ought to be examined for specific population groups or population in geographical areas in cases they are affected differently and disproportionally by the R&I.

[19] Life-cycle analysis is outside the scope of the Impact Monitor project

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WHO provides recommendations for health impacts resulting from environmental noise and from air quality:

- Noise: Cardiovascular disease, annoyance, cognitive impairment, hearing impairment and tinnitus, adverse birth outcomes, quality of life, wellbeing and mental health, metabolic outcomes, and sleep disturbance [30];
- Air quality: Air quality levels for $PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2, and CO [31].

Well-known and generic indicators to quantify health impacts in non-monetary terms are (cf. Tool #32 in the EC's Better Regulation Toolbox [9]):

- Quality adjusted life years: Using available information on objective improvements in health/quality of life and combining it with the duration of that improvement;
- Healthy life years: Indicating the number of years a person of a certain age can expect to live without disability;
- Disability adjusted life year: Indicating the number of quality adjusted years lost because of illness/disability;
- Years of potential life lost: Indicating the years a person would have lived if not died prematurely.

Two examples of types of methods to quantify health impacts in monetary terms (while emphasising that these methods cannot and do not seek to place a monetary value on life) are (cf. Tool #32 in the EC's Better Regulation Toolbox [9]):

- Preference-based methods

  A preference-based method aims to compare the benefits of different R&Is by placing an implicit monetary value on health benefits. It analyses individuals' stated or revealed preferences with respect to small changes in low-probability risks, measuring the individuals (or populations) willingness-to-pay and/or willingness-to-accept compensation for a preferred R&I or for a worsening of certain conditions. For example, measuring the value of statistical life and the value of statistical life year.

- Accounting-style methods

  An accounting style method measures only certain aspects of health impacts in terms of cost of illness. A cost of illness method comprises only the medical expenses related to the incidence of an illness.

D.3 Capacity, efficiency and predictability

The SESAR Performance Framework [26] addresses the measurement of the performance of SESAR operational improvements, including the measurement of indicators related to capacity, efficiency and predictability. To give a mere glimpse of the quantification of these indicators:

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- Capacity
  - Number of movements per volume of TMA or en-route airspace per hour for specific traffic mix and density;
  - Number of movements / departures / arrivals per one runway per hour for specific traffic mix and density;
  - Reduction in number of unaccommodated flights.
- Efficiency
  - Fuel efficiency
    - Amount of fuel burnt divided by number of flights;
    - Amount of fuel burnt on stand divided by number of flights;
    - Amount of fuel burnt in taxi-in/taxi-out phase divided by number of flights;
    - Amount of fuel burnt in TMA during departure / arrival divided by number of flights;
  - Operational efficiency
    - Average delay (difference between actual off-block time and scheduled off-block time) per flight;
    - Percentage of departures with difference between actual off-block time and scheduled off-block time less than 3 / 5 / 10 / 15 minutes.
- Predictability
  - Average and variance of the distribution of the differences between flown trajectories and flight plans or reference business trajectories;
  - Average and variance of the distribution of actual taxi-in/taxi-out times versus planned taxi-in/taxi-out times;
  - Average and variance of the distribution of actual turnaround durations versus planned turnaround durations.

D.4 Societal impact

With reference to Tool #30 in the EC's Better Regulation Toolbox [9], societal impacts are diverse, complex (affecting different population subsets and economic sectors), and strongly connected with economic and environmental impacts. Hence, there may be trade-offs where societal impacts point in different directions and a combination of qualitative and quantitative analyses is used (e.g. as many societal impacts may not be quantifiable and models available might rely on controversial assumptions).

This subsection paraphrases Tool #30 in the EC's Better Regulation Toolbox, with a focus on employment, working conditions, and income:

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- Employment

  When analysing impacts on the level of employment, the main question is whether there will be more or fewer jobs (or hours worked) overall or for specific stakeholder categories, in a specific geographical area. The following questions may assist in exploring various dimensions of employment impacts:

  - To what extent are new jobs created or lost?
  - Are direct jobs created or lost in specific sectors, professions, qualifications or regions, or a combination thereof? And what specific social groups are affected?
  - Are there indirect effects that might change employment levels?
  - Are there any factors that prevent or enhance the potential to create jobs or prevent job losses?
  - To what extent does the R&I influence the availability and willingness of workers/specific groups to work?

- Working conditions

  The following questions may assist in exploring various dimensions of impacts on working conditions: Does the R&I affect:

  - Wages, labour cost and/or wage setting mechanisms?
  - (Directly or indirectly) employment protection?
  - Risk of undeclared work?
  - Work organisation?
  - Affect health and safety at work?
  - Access to vocational education and training and to career development/advice?

  See also the SESAR Performance Framework [26] for a few more concrete examples on measuring human performance, such as measuring:

  - Consistency of the human role with respect to human capabilities and limitations;
  - Suitability of the technical system in supporting the tasks of human actors;
  - Adequacy of the human-machine interface in supporting the human in carrying out his/her tasks;
  - Adequacy of the team structure and team communication in supporting human actors;
  - Adequacy of the team composition in terms of identified roles;
  - Adequacy of the task allocation among human actors;
  - Use acceptability of the proposed ATM concept.

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- Income

  Impacts on income mainly relate to social fairness. The following questions may assist in exploring various dimensions of impacts on income (distribution): Does the R&I affect:

  - People/households' income?
  - Inequalities and distribution of incomes and wealth?

A quantitative analysis can be easier undertaken when assessing impacts on employment and income (because these are quantitative in nature) than on working conditions. The latter are often of qualitative nature. Quantitative approaches to assess societal impact range from relatively simple measurements, mainly based on past observations, to counterfactual analysis and up to highly complex formalised (and data-hungry) models, like computable general equilibrium models or econometric models of the (world) economy.

For societal impacts, net effects may not be very informative, since in the presence of important distributional effects, global (aggregate) figures could be misleading as they might hide controversial trade-offs. Also, the functioning of the labour market and different institutional settings can influence the direction and the magnitude of the social impacts. Those differences require an analysis at a national level or alternatively grouping of countries in clusters based on the similarity of their institutions. Further, in case impacts are not economy-wide but concern a specific sector only, it is recommended to refer to a NACE classification sector (as moving away from the NACE classification [13], consistent and reliable data are more difficult to get), whereas for regional impacts it is recommended to align with the NUTS classification [14].

D.5 Cost and benefits

Chapter 8 in the EC's Better Regulation Toolbox [9] is mainly devoted to cost and benefits. This subsection is essentially based on that chapter.

Cost of one stakeholder may be a benefit to another. Cost and benefits can be direct and indirect, private and societal, and one-off and recurrent. Simulation models are commonly used, which include general equilibrium models (which allow for consistent comparative analysis by ensuring that the economic system and individual markets remain in equilibrium in the long term), econometric models (which capture medium-/long-term effects from shocks and for forecasting using historical time-series data), partial equilibrium models (which are used in the detailed analysis of one or more specific economic sectors over the short/medium/long term), and micro-simulation models (which are typically used for analyses at a detailed disaggregated level over the short term focusing on specific stakeholders. An example of an equilibrium model listed in Appendix B, is AERO-MS.

To evaluate the administrative-cost impact of an R&I (and in particular that of a policy), the EU Standard Cost Model could be applied. The main aim of this model is to evaluate the net cost of administrative obligations. The administrative net cost are addressed by multiplying the average cost of the required administrative activity with the total number of activities performed per year and by subtracting the cost of administrative activities removed.

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D.6 Competitiveness, competition and internal market

Tools #21, #24 and #25 in the EC's Better Regulation Toolbox [9] deal with competitiveness, competition and internal market.

- Competitiveness

  Competitiveness is directly related to productivity. Productivity is determined by changes in the quality and quantity of inputs and technological progress.

  For R&I that is likely to have only a limited impact on competitiveness or for which it can be shown based on expert's judgement that a deeper analysis would be disproportionate, the impact assessment or monitoring may be mainly qualitatively. In that case a short analysis could suffice, by addressing elements such as:

  - Affected sectors;
  - Identified impacts on these sectors;
  - Qualitative estimate of the nature and magnitude of impacts (e.g. How big is the expected impact? Is it a direct or indirect result? When is it expected to occur?);
  - Probability that impact will take place (e.g. How likely is the impact? Does it depend on critical assumptions?).

  For quantitative assessments or monitoring, models such as computable general equilibrium and macro-econometric input-output models can be used. Possible outputs can be:

  - Performance of affected sectors (e.g. labour productivity, profitability (as measured by net profit margin) and market share of the world market);
  - Cost, prices and revenues per stakeholder.

- Competition

  Competitive markets are considered to encourage enterprises to be efficient and innovative, thereby reducing prices and improving the quality of goods and services. When policies intervene in markets to regulate the behaviour of actors in that market, this may restrict competition.

  If the R&I under investigation is a policy, a deeper analysis can be appropriate in case this R&I:

  - Limits the number or range of suppliers and producers; or
  - Limits the ability of suppliers and producers to compete; or
  - Reduces the incentive of suppliers and producers to compete; or
  - Limits the choices and information available to customers.

  In those cases, the following criteria (although not all criteria may be relevant) may be helpful:

  - Impact on existing stakeholders, e.g.

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- Impact on cost to meet policy regulation;
- Impact on exit of stakeholder's company;
- Impact on anti-competitive behaviour of stakeholders;
- Impact of state aid measures.
- Impact on entry of new stakeholder's companies, e.g. restriction of entry and limitation of access to specific resources.
- Impact on customer prices, e.g. identification of likely causes.
- Non-price impacts on customers, e.g. impact on quality and variety of products, and impact on incentive to innovate.
- Impact on upstream and downstream markets, e.g. impact on anti-competitive behaviour of stakeholders, and incentive to increase vertical integration.

- Internal market

  Impact assessments or monitoring addressing internal markets (e.g. national or EU) could relate to the investigation of the impact on the movement of people, goods, services, and capital. So, key questions would be: What impact does the R&I have on the (free) movement of persons, goods, services, and capital? Will the R&I affect customer choice and prices? Will the R&I create/eliminate barriers for new suppliers and service providers?

  An analysis may likely be qualitatively, mainly because of challenges to difficulties in quantifying cost and benefits. Taken from the EC's Better Regulation Toolbox and within the context of a Single Market, the next examples may be of help:

  - Trade creation and diversion

    Export/import to GDP, degree of price and wage dispersion/convergence, and preference to trade within EU rather than outside world.

  - More competitive markets

    Foreign direct investments to GDP.

  - Efficiency gains

    Unit labour cost.

  - Innovation

    Expenditure in research, development and innovation, number of personnel employed in research, development and innovation, and number of patents.

  - Free movement of people

    EU citizens working in another Member State as percentage of total labour force, number of exchange students, and cross-border mobility between EU Member States and in other regions (e.g. Unites States, Canada or Australia).

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D.7 Research and innovation

Tool #22 in the EC's Better Regulation Toolbox [9] deals with research and innovation. Of all R&I in aviation (and especially in case the R&I under investigation is a policy) can impact research and innovation, e.g. they can create barriers as well as opportunities to research and innovation. Addressing this impact can often be qualitative only, by considering and elaborating questions such as:

- Does the R&I impact the generation of new ideas (or their adaptation and application)?
- Does the R&I affect the cooperation between stakeholders?
- Could the R&I add or ease the burden of testing, piloting or demonstrating research and innovation in aviation?
- Could the R&I affect the introduction of innovations in new technologies, operations or policies?
- Can the R&I change the innovation incentives and choices for investments in research and innovation in aviation?

D.8 Education and training

Education and training are addressed in Tool #31 in the EC's Better Regulation Toolbox [9]. The identification of potential impacts on education and training essentially boils down to the question: Does the R&I under investigation have an impact on the need for individuals (or groups of individuals) to upgrade their level of knowledge, skills and competences, as well as their ability to sustain employment, growth and innovation?

When considering impacts of education and training, impacts on different education and training sectors need to be considered. These include preschool, primary/secondary school, vocational education and training, and higher education. These impacts need to be considered in the light of different societal groups/age cohorts, regions, and sectors.

The SESAR Performance Framework [26] gives a few more concrete examples on measuring impact on education and training, such as measuring (with the guidance from SESAR PJ16) the feasibility of the new ATM concept in relation to changes in:

- Competence requirements through the identification of knowledge, skills and experience and of the potential interferences between existing and new knowledge and skills;
- Staffing levels, shift organisation and workforce relocation through the identification of the impact on staff level, on shift organisation, and on workforce relocation;
- Recruitment and selection requirements through the identification of changes in operator profile and in selection criteria;
- Training needs with regards to its contents, duration and modality through the identification of the content, duration and type of training (e.g. classroom, simulator, on-the job, and e-learning).

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