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AI Watch Index

Policy relevant dimensions to assess

Europe's performance in artificial intelligence

Joint Research Centre

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Contents

Foreword

This report is published in the context of AI Watch, the European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe, launched in December 2018.

AI has become an area of strategic importance with potential to be a key driver of economic development. AI also has a wide range of potential social implications. As part of its Digital Single Market Strategy, the European Commission put forward in April 2018 a European strategy on AI in its Communication "Artificial Intelligence for Europe" COM(2018) 237. The aims of the European AI strategy announced in the communication are:

- To boost the EU's technological and industrial capacity and AI uptake across the economy, both by the private and public sectors
- To prepare for socio-economic changes brought about by AI
- To ensure an appropriate ethical and legal framework.

In December 2018, the European Commission and the Member States published a "Coordinated Plan on Artificial Intelligence", COM(2018) 795, on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation.

Subsequently, in February 2020, the Commission unveiled its vision for a digital transformation that works for everyone. The Commission presented a White Paper proposing a framework for trustworthy AI based on excellence and trust.

AI Watch monitors European Union's industrial, technological and research capacity in AI; AI-related policy initiatives in the Member States; uptake and technical developments of AI; and AI impact. AI Watch has a European focus within the global landscape. In the context of AI Watch, the Commission works in coordination with Member States. AI Watch results and analyses are published on the AI Watch Portal (https://ec.europa.eu/knowledge4policy/ai-watch_en).

From AI Watch in-depth analyses we will be able to understand better European Union's areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education, and society.

AI Watch is developed by the Joint Research Centre (JRC) of the European Commission in collaboration with the Directorate-General for Communications Networks, Content and Technology (DG CONNECT).

This report addresses the following objectives of AI Watch: develop a structured set of AI indicators –the AI Watch Index– covering the various dimensions of AI relevant for policy making. The report presents an approach for the identification and systematic production of useful indicators to understand better Europe's areas of strength and those deserving attention, thereby covering the various dimensions of AI relevant for policymaking.

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Abstract

This report illustrates and follows the steps to build an AI Watch Index from the collection of outputs of AI Watch analyses. It identifies a set of indicators suitable to provide a comprehensive and balanced overview of the various topics addressed by the research activities carried out within AI Watch. The aim of this index is to provide quantitative indicators on several policy relevant dimensions in order to assess the performance and positioning of the EU and its Member States in Artificial Intelligence.

The report describes first a suitable approach for identification of indicators. The methodology aims to identify, select, and collect a number of policy relevant indicators that allow, as much as possible, cross-country and temporal comparability in the evolving international economic, social, industrial and research landscape of artificial intelligence. Then, the report proposes a list of indicators, thoroughly described and organised along the main dimensions covered by AI Watch's activity.

Executive summary

The AI Watch Index presented in this report provides a structured set of indicators to understand the performance and positioning of the EU in artificial intelligence (AI), in quantitative terms. The proposed indicators are selected from the activity performed within the realm of AI Watch, in an attempt to monitor the development, uptake and impact of AI in Europe and beyond. The selection of indicators has followed a process of identification and screening to ascertain that a relevant, useful, and scientifically sound picture of the positioning of Europe and its Member States in AI can be provided. Metadata facilitates the understanding of the variables measured and indicators' usefulness, and also replicability in the case that all data are available.

The geographical coverage and granularity of the indicators vary, depending on the concepts covered and data availability. Most indicators are provided for the entire world, allowing for comparative analysis of the EU with the US, China, and other world main actors. In terms of granularity, most indicators are computed at least at country level, covering all EU Member states and the EU aggregate. A few indicators are available only at aggregate level by definition, e.g. the diversity indices, computed for conferences that take place around the world with international participation and for which a geographical classification is not pertinent.

The 28 indicators are organised around 6 dimensions, as shown in the figure below. They reflect policy relevant areas and are interlinked with sectoral and transversal policies with an impact in the European economy and society:

- **Global view on the AI ecosystem**: sets the basis for understanding the global AI ecosystem, and covers aspects related to the importance of the worldwide AI landscape, AI areas of strength and AI investments.
- **Industry**: presents AI firms' profiles and also includes a focus on robotics start-ups, in order to understand the characteristics of the AI industry.
- **Research and Development**: elaborates on the EU's capabilities and strengths in research, covering various aspects of R&D activity (e.g., patenting, publications and EU funded projects) and network of collaborations.
- **Technology**: analyses AI as a general purpose technology, in aspects such as technological enablers, performance of AI and standardisation.
- **Societal aspects**: covers two sub-dimensions: diversity in research, including gender diversity, and higher education offer in AI
- **AI in the Public sector**: covers public procurement of AI, and AI patents for the public sector.

The next steps will consist in the systematic collection of data for each indicator, the online presentation of the index in the AI Watch portal and, at a later stage, an online visualisation. To facilitate usability, interpretation and replicability, the online dissemination of the indicators will be accompanied by individual fiches including the detailed description of each indicator, as presented in this report.

Summary of AI Watch Index indicators by dimension

AI Watch Index dimension	AI Watch Index sub-dimension	Indicator name
G. Global view on the AI ecosystem	AI activity	G1: AI economic agents G2: AI economic activity intensity
	AI areas of strength	G3: Comparative Advantage in AI areas G4: AI thematic hotspots G5: Comparative advantage in robotics' trade
	AI investments	G6: AI investments
I. Industry	Industry	I1: AI firms' profile I2 Robotics start-ups
R. Research and Development	R&D activity	R1: AI economic agents in AI R&D R2: AI R&D Activity score R3: Intensity of AI research activity

AI Watch Index dimension	AI Watch Index sub-dimension	Indicator name
	Network of collaborations	R4: AI R&D collaborating regions R5: Peer-to-peer collaborations R6: Strategic position in the network of collaborations
T. Technology	Technological enablers	T1: AI in APIs
	Performance of AI	T2: Performance of AI research
	Standardisation	T3: Standardisation activity engagement
S. Societal aspects	Diversity in research	S1: Gender diversity index S2: Geographic diversity index S3: Business diversity index S4: Conference diversity index
	Higher education	S5: AI in university programmes S6: University places with AI content S7: AI intensity in university places
P. AI in the Public sector	Public procurement	P1: Public values in EU public procurement P2: Entrepreneurship for the public sector P3: Investments by the public sector's procurement
	AI patents for the Public sector	P4: Patents for the public sector

Source: Authors' elaboration.

1 Introduction

AI Watch monitors European Union's industrial, technological and research capacity in AI; AI-related policy initiatives in the Member States; uptake and technical developments of AI; and AI impact. AI Watch has a European focus within the global landscape. Results from AI Watch in-depth analyses make possible to understand better European Union's areas of strength and areas where investment is needed. In the framework of its different activities, AI Watch develops indicators aiming to inform policy decision-making. Such indicators give insights into different aspects of AI, reflecting the set of topics covered by the AI Watch knowledge service and accessible on the AI Watch web portal (Figure 1).

Recent activity from AI Watch includes:

- Development of an **operational definition of AI** adopted for the monitory activities of AI Watch, and presented in a report.
- An **AI history timeline** that includes selected important AI breakthroughs since the 1950's, presented in a report and visualisation tool.
- **AIcollaboratory.org:** online platform to collect and explore AI results, progress and capabilities.
- Overview and analysis of the **worldwide AI landscape**: online dashboard and report providing several perspectives on areas of specialisation (e.g., Machine Learning, Autonomous vehicles, etc.) and on industry and R&D from an ecosystem perspective.
- Analysis of **national strategies on AI**, presented in a report.
- Development of methodology and estimation of **AI investments in the EU** in 2018.
- Development of a methodology to monitor the **uptake and impacts of AI applications** across the economy, and application to the **health sector**.
- Development of a methodology report to study the **EU robotics market shares**.
- Proposal of a framework to analyse the **use and impact of AI in public services**.
- A multidisciplinary investigation about the **impact of AI systems on human behaviour**, with three goals: (1) to advance the scientific understanding of machine and human intelligence; (2) to study the impact of algorithms on human behaviour, especially on decision making and cognitive and socio-emotional development; and (3) to provide insights to policy makers with respect to the previous issues.
- More recently, AI Watch also covers the tracking and study of standardisation activities in AI.
- Additionally, **Impact of AI on society** is analysed in several research projects closely linked to AI Watch, including analysis of academic offer in advanced digital technologies, estimation of number of places offered to students in such technologies, and the study of diversity in research.

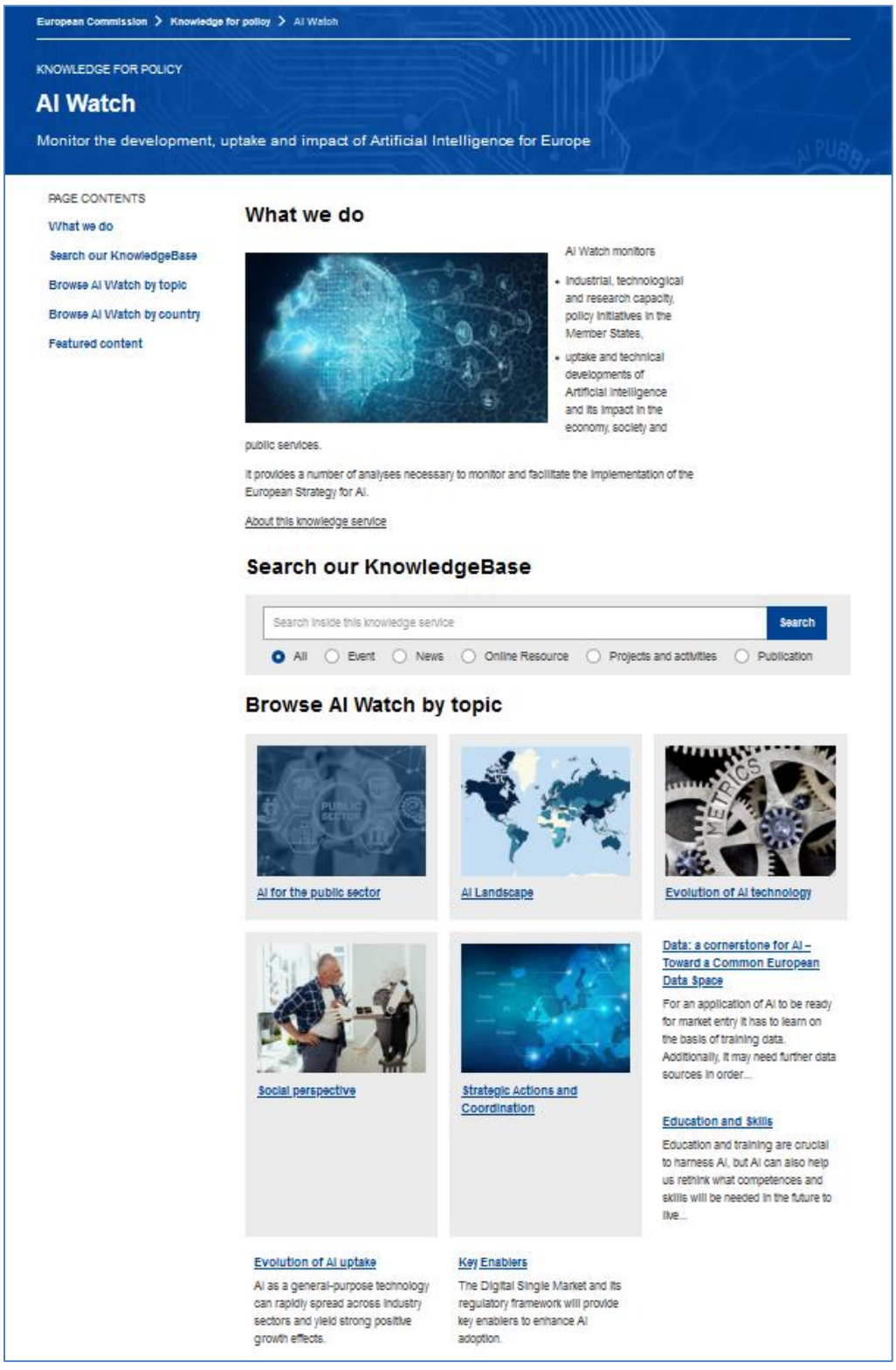
To provide a comprehensive overview of the main aspects characterising AI, its evolution and technological development, as well as the relative position of Europe in the global AI landscape, the AI Watch knowledge service proposes an AI Watch Index. This index shall group a selected number of indicators offering an overview of key aspects for policy making, presented in an easy-to-read format aiming to facilitate broad understanding. The AI Watch Index ensures a wide coverage of socio-economic aspects, providing an independent and scientifically sound assessment of AI and its impacts, with especial attention given to research and industrial developments, technological enablers, robotics, AI in public services, education, and standardisation.

The main steps which have been followed in the creation of the index are:

1. Identification and screening of potential indicators, with contribution from the different activities of AI Watch, and selection of the indicators to be part of the index.
2. Development of a structured set of indicators (the AI Watch Index itself) and their organisation around dimensions relevant for policy making.

Section 2 of the report covers the methodological steps for the construction of the indicators. It also presents the template used to collect information on the indicators from AI Watch activities, and the dimensions around which the selected indicators are organised: global view on the AI ecosystem, industry, research and development, technology, societal aspects, and AI in the public sector. Section 3 provides a detailed description of each of the 28 indicators identified. Section 4 presents the conclusions and next steps of this work.

Figure 1. AI Watch Portal



Source: AI Watch site: https://knowledge4policy.ec.europa.eu/ai-watch_en (visited of February 08 2021)

2 AI Watch Index

This section provides an overview of the steps that have been followed to identify, collect, select and organise the set of indicators arising from AI Watch activities. The overall aim of such a set of indicators is to facilitate access to relevant insights and interpretation of evidence in order to provide better and effective support to policy decision-making.

2.1 Construction of the AI Watch Index: an overview

The first step in the construction of the AI Watch Index consisted in the systematic analysis of the contributions from all the activities covering different topics in AI Watch, to identify and screen suitable indicators. Indicators should serve to summarise the wide range of information identified during the research activity in each of the addressed topics. Efforts have been carried out to identify suitable indicators in all of the AI dimensions analysed by AI Watch activities.

To set a common basis for the collaborative activity of construction of the indicators, we first reviewed and agreed on the terminology involved in the construction process, in particular with respect to the concepts indicator, variable, value and data. Some useful definitions are provided in Box 1 and in Figure 4 of Annex 1. *Definitions and Criteria for indicator selection*Annex 1. In summary, we first define the variables[1] that we want to measure to explain characteristics of the population under study. The universe or population is approximated by the population framework, or set of units of the population on which we can actually perform measurements. Then we collect data about these variables in the population framework, and compute the indicators. For instance, if the population under study is the AI industrial ecosystem, we may want to know some of its characteristics, e.g., the size of AI firms. An indicator to proxy this is the number of firms in the measurable ecosystem by size class. The size of a firm can be defined in multiple ways, or in other words, by using different variables (e.g. number of employees, revenue…). Once the variable is selected and defined, it can be quantified by using data from the available sources or obtained through different data collection methods, such us surveys, administrative registers, or privately-owned firms repositories. After the data is collected, they can be aggregated by e.g. geographic area and year, into the indicator of interest, size of AI firms. All this exercise needs clear definitions of population units, variable, and aggregation measures.

Indicator selection tries to maximise the number of desirable criteria that indicators should fulfil, as reflected in Box 2 and Box 3 in Annex 1. Overall, indicators should be generally relevant –purposely related to a topic of interest-, scientifically sound, meet user-specific needs –policy relevant, understandable, acceptable, computable in a way that is proportionate to resources-, and, in this particular setting, be useful in the international context, as AI Watch has a European focus within the global landscape. Priority has been given to indicators with wide geographical coverage, to allow for international comparisons. However, some indicators, by definition or due to the source used, are available for the EU only. Other indicators reflect the reality and advancements of AI as a scientific field, with no geographical dimension specified.

As far as data sources are concerned, the variety of indicators composing the proposed index is derived from multiple sources. In some cases these are produced by AI Watch. Official or publicly accessible data are also used directly for some indicators (e.g. EU's Tenders Electronic Daily (TED), UN Comtrade, EPO PATSTAT). While the purpose of this report is not to explain in detail the data sources and methodologies that have been used to provide the abundant information publicly provided by AI Watch, some examples of sources used follow[2]. First, the techno-economic segment analytical approach (TES) produces a unique dataset feeding many of the index indicators. It is based on the combination of private and public sources which are queried to identify specific AI activities and the economic agents that perform them. This dataset allows us to analyse the characteristics of the AI industrial and R&D landscape from an ecosystem-based perspective. Then, other sources include: privately owned datasets, like Dealroom, to select robotics start-ups; results of collaborative projects, such as ai.collaboratory.org for AI performance indicators and technological progress, or divinAI.org, which tracks participation in AI conferences to calculate diversity indices.

The vast majority of the proposed indicators are ready to be computed, and to be provided on a regular basis as long as the measurement exercises are continued. In addition, some indicators are proposed in the exploratory phase, and their calculation is conditional on the successful development of the methodology and its eventual approval. This is the case of the three indicators on public procurement (subsection 3.6.1).

[1] Variables are observable attributes of population units that may be quantitatively represented by a numeric value (e.g. age, occupation, industry, etc.).

[2] More detailed information can be found in the references mentioned in the fiche for each indicator.

Information on the indicators has been collected using a common template, to make sure that the necessary data allowing for a systematic collection, interpretation, replicability and categorisation of each of the indicators is made available. For instance, providing contextual information on why the indicator is proposed, and what it intends to measure is essential for users. Additional useful information includes, but is not limited to: explanation of important underlying concepts, reference date, reporting frequency, geographical coverage and granularity, etc. Other information that may be of relevance refers to signalling whether the indicator has been used in the past or in other contexts (literature and bibliographic references).

2.2 Metadata

This subsection shows the metadata used to describe the indicators that are proposed as part of the AI Watch Index. The template depicted in Figure 2 has been used for the systematic collection of metadata, and is presented for dissemination and discussion.

Figure 2. Template for indicator description

FIELD	DESCRIPTION
Indicator name	Full name of the indicator
Rationale	Short description of the reason why the specific indicator is proposed for inclusion and how it will be useful
Definition	Indicator definition: it explains all terms and elements of the indicator to ensure consistent interpretation and that intended measurements are reliably collected. An equation or description of calculations required to derive the data may be included. If the indicator is a percentage or ratio, there must be a description of the numerator and denominator.
Unit of measurement (Data type)	Unit of measurement (e.g., number of activities, percent of companies) must be indicated. Minimum or maximum values should be included, if applicable. Indicate if the number is cumulative or specific to the reporting frequency. Data types include, but are not limited to: Integer: A whole number having no decimal places (e.g., number of people trained). Decimal: The number is expected to have a decimal (optional: how many decimal places must be tracked). Percentage: Both numerator and denominator must be defined. Proportion/Ratio: Both numerator and denominator must be defined . Currency.
Geographical coverage	Coverage of the data provided: World, EU27 …
Geographical granularity	Geographical granularity in which the indicator is (or may be) available: World, Country, Region (NUTS2)…
Breakdown	Provided or potential breakdowns of the indicator, i.e., if the indicator is (or is expected to be) presented in combination with another variable (e.g. number of economic agents (indicator) by organisation type (breakdown variable))
Data source(s)	Specific sources of data must be identified. If indicators are produced with data not produced by AI Watch itself, the original sources are reported.
Reference date	Date to which the value of the indicator refers to: it may be a specific date (e.g. 31-12 2019), it may be a period (e.g. year 2019, period. 2010-2019).
Reporting frequency	Frequency with which the indicator may be computed and data reported: quarterly, semi-annual, annual, irregular.
Known limitations	Any major data limitations must be indicated. Plans on how to address these limitations may be stated.
References and Comments	Any additional comment which is considered useful in order to fully grasp the meaning and relevance of the indicator. This may include references to published reports in which the indicators are further described or used.
Foreseen availability	Date in which the indicator is expected to be available

Source: Authors' elaboration based on USAID (2016).

2.3 AI Watch Index dimensions

As described in Section 3 the proposed AI Watch Index is composed by **28 indicators** grouped in **6 dimensions** and **13 sub-dimensions**. The dimensions are depicted in Figure 3 and described in this subsection. They have been delineated following a twofold approach: bottom-up, by analysing the wealth of information emanating from AI Watch activities; and top-down, considering dimensions that are policy relevant and relate to sectoral and transversal policies with an impact on the European economy and society. In particular, the dimensions covered by the index reflect the policy oriented activity of AI Watch, in turn driven by the monitoring needs announced in the European Strategy on AI[3] and its coordinated plan[4]. These are also aligned with the policy directions introduced in the White Paper on AI[5]. Boosting the EU's technological and industrial capacity on AI, and preparing for socioeconomic impacts, two of the three pillars of the European Strategy on AI, are reflected in the AI Watch Index. The index includes aspects such as digital skills, digital inclusion, technological breakthroughs, investments, industrial strengths, excellence networks, etc., all of them tackled and reinforced, in coordination with Member States, by the Coordinated Plan on AI.

The proposed AI Watch Index shares many commonalities with similar initiatives, such as Stanford's AI Index 2021 Annual Report (Zhang et al., 2021)[6]; the State of AI Report 2020 (Benaich and Hogarth, 2020)[7], the OECD AI Policy Observatory[8], and the Global AI Index (Tortoise Media, 2020)[9]. All of these indices are useful to analyse the position of individual countries in important facets, and to assess performance over time. The main advantage of the proposed AI Watch Index, when compared to other initiatives, derives from the policy orientation of AI Watch: the index is composed by indicators produced within the realm of AI Watch activities, and aim to monitor several aspects of the European Strategy on AI and the Coordinated Plan on AI. Additionally, the proposed index has better and more granular geographical coverage than that of the mentioned indices. On the one hand, most of AI Watch Index indicators are available for all the EU Member States (with exceptions when the concept measured is not relevant at country level). This is not the case of e.g. the Stanford's AI Index, which mostly compares the top international players, often mentioning the EU and in some cases the top EU Member States; or Benaich and Hogarth's State of AI Report 2020, with a focus on the AI activity, but not so much on geographical comparability. On the other hand, many of the AI Watch AI index indicators can also be provided at regional level[10], thus allowing to identify local hubs of AI activity.

The six main dimensions of the AI Watch Index are:

G: Global view on the AI ecosystem. This dimension portrays the AI ecosystem from an economic perspective, with a focus on the EU and including international comparison. It is meant to provide an overview and to frame the remaining dimensions. It includes three sub-dimensions: ***AI activity***, with indicators reflecting the size of the worldwide AI economic activity, both in absolute terms and relative to the economic size of the countries; ***AI areas of strength***, showing the prevalence of AI subdomains across countries and their specialisation patterns; and ***AI investments***, providing an overview of investments by public and private organizations to develop and implement AI.

I: Industry. This dimension focuses on AI-related industrial activity, as one of the pillars of AI production and diffusion. It presents detailed information about AI firms' profile in terms of firm demographics and AI business type. It also covers a focus on robotics start-ups, as one of the AI-related areas in which the EU stands out and has revealed comparative advantage[11].

R: Research and Development. One of the known strengths of the EU is its research activity, supported by high-level academic production and a nurtured network of inter-country collaborations. This dimension of the AI Watch Index presents indicators on R&D activity developed by all types of actors: research institutions,

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3 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "Artificial Intelligence for Europe" COM(2018) 237 final, 25.4.2018.

4 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions "Coordinated Plan on Artificial Intelligence" COM(2018) 795 final, 7.12.2018.

5 "White paper on AI - A European approach to excellence and trust" COM(2020) 65 final, 19.2.2020.

6 It considers the following domains: Research and Development, Technical Performance, The Economy, AI Education, Ethical Challenges of AI Applications, Diversity in AI, and AI Policy and National Strategies.

7 It considers the following dimensions: Research, Talent, Industry, and Politics, plus a section on Predictions.

8 The OECD Policy Observatory show data and visualisation on the following areas: AI news, AI research, AI coding, AI search & trends, AI jobs & skills, and recently added Live COVID-19 research. https://oecd.ai/, last visited on 12 March 2021.

9 The Global AI Index is underpinned by 143 indicators split across seven sub-pillars: Talent, Infrastructure, Operating Environment, Research, Development, Government Strategy and Commercial. https://www.tortoisemedia.com/intelligence/global-ai/, last visited on 12 March 2021.

10 NUTS2 level under the Nomenclature of territorial units for statistics (NUTS): https://ec.europa.eu/eurostat/web/nuts/background

11 JRC report "TES analysis of AI Worldwide Ecosystem in 2009-2018", Samoili et al. (2020).

firms and governmental agencies. The types of activities considered cover patenting activity, publications and EU funded projects. The indicators proposed are grouped around two sub-dimensions: ***R&D activity*** and ***Network of collaborations***.

T: Technology. This dimension groups together three sub-dimensions related to the development of AI as a cross-cutting multi-purpose technology. It encompasses adoption of AI in application programming interfaces (APIs) as ***Technological enablers***; performance of AI specific tasks, e.g. face recognition, to account for technological breakthroughs under ***Performance of AI***; and ***Standardisation*** activities enabling interoperability and fostering innovation, efficiency and growth.

S: Societal aspects. Diversity in research and education are among the aspects in which AI can have an impact and, conversely, can impact the development of AI. In the sub-dimension ***Diversity in research*** the indicators analyse how diverse is research in the AI field with respect to authorship gender, geography and institutional affiliation. Under the sub-dimension ***Higher education***, indicators present the characteristics and intensity of higher education programmes and university places offered to students involving AI as a learning subject.

P: AI in the Public sector. AI can bring multiple benefits to the public sector, from AI-assisted decision making to improved service provision to the population. AI-enabled solutions apply to all levels of governance, providing an opportunity to improve the efficiency and effectiveness of service delivery, with impacts on citizen satisfaction. This dimension incorporates indicators related to ***Public procurement*** of AI, and on ***AI patents for the Public sector***. The indicators from this dimension are experimental and are therefore proposed in the exploratory phase. Their development would require further research and methodological work, before their eventual inclusion in the index. Therefore, they are tentatively proposed, and their provision is subject to the satisfactory result of the research.

Figure 3. Summary of AI Watch Index indicators by dimension

AI Watch Index dimension	AI Watch Index sub-dimension	Indicator name
G. Global view on the AI ecosystem	AI activity	G1: AI economic agents
		G2: AI economic activity intensity
	AI areas of strength	G3: Comparative Advantage in AI areas
		G4: AI thematic hotspots
		G5: Comparative advantage in robotics' trade
	AI investments	G6: AI investments
I. Industry	Industry	I1: AI firms' profile
		I2 Robotics start-ups
R. Research and Development	R&D activity	R1: AI economic agents in AI R&D
		R2: AI R&D Activity score
		R3: Intensity of AI research activity
	Network of collaborations	R4: AI R&D collaborating regions
		R5: Peer-to-peer collaborations
		R6: Strategic position in the network of collaborations
T. Technology	Technological enablers	T1: AI in APIs
	Performance of AI	T2: Performance of AI research
	Standardisation	T3: Standardisation activity engagement
S. Societal aspects	Diversity in research	S1: Gender diversity index
		S2: Geographic diversity index
		S3: Business diversity index
		S4: Conference diversity index
	Higher education	S5: AI in university programmes
		S6: University places with AI content
		S7: AI intensity in university places

P. AI in the Public sector	Public procurement	P1: Public values in EU public procurement P2: Entrepreneurship for the public sector P3: Investments by the public sector's procurement
	AI patents for the Public sector	P4: Patents for the public sector

Source: Authors' elaboration.

3 Selection of indicators

3.1 Global view on the AI ecosystem [G]

3.1.1 AI activity

Indicator name	*G1: AI economic agents*
Rationale	It measures the size of the AI landscape. It measures the level of involvement of a geographical area (country, region…) in the worldwide AI landscape. Useful for cross-country comparison. The breakdown per organisation type enables further analysis of the relationships between research and industry, research and government and industry and government in different geographic areas, and allows the assessment of different properties of the whole ecosystem and local areas.
Definition	Number of economic agents in the AI ecosystem. Agents may be research institutes, universities, firms, laboratories, or governmental institutions, grouped into 3 types: research institutes, firms and governmental institutions. Further details: The category “governmental institutions” includes the institutions owned by the state, or with public administrative functions, which do not have an explicit research portfolio (i.e., excludes universities and research institutions, which fall under ""research institutes""). In the category “research institutes”, all agents mainly devoted to research activity are encompassed, i.e. private research centres, public research centres, universities , university/academic spin-offs, and industrial research centres exclusively dedicated to research activities. Departments of a same university are not considered as separate agents."
Unit of measurement	Number of agents (integer, percentage)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Organisation type: research institute, firm or governmental institution.
Data source(s)	JRC AI TES Dataset It is a multisource microdata dataset built by considering the main AI-related industrial, innovation and research activities, and all the economic players that are involved in them (i.e. firms, research institutes, governmental institutions). The TES approach takes into account information about location, technological aspects, and interactions, in order to build a holistic and interconnected view of the worldwide AI ecosystem from 2009 to 2020.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	It does not address the relative importance of players, but their presence in the landscape. This limitation is overcome by the introduction of indicators addressing the level of involvement (number of AI R&D activities). This indicator does not consider the size of the economy of the geographic area. This is overcome by the consideration of the indicator relative to GDP.
References and Comments	The economic agent (or player) is expected to have an active role in the techno-economic segment, with the capability to influence its economic development and future evolution. In this sense, the focus is set on the organisations, and not on individuals, namely the applicant organisation owning the invention in the case of patents, authors´ affiliation in conference proceedings, companies, governmental entities, etc. To establish a comprehensive landscape, we target both industrial and R&D activities. This helps to capture economic agents that participate in the landscape with a variety of foci, interests and impact capacity.

Indicator name	*G1: AI economic agents*
	Therefore, players' economic activities of interest for the analysis of the TES ecosystem include R&D processes (research and innovative developments), general economic processes (industrial production, trade, marketing and other services), firms funding (venture capital funds or other types of investment). *As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	*G2: AI economic activity intensity*
Rationale	It measures the presence of AI economic agents with regard to the size of the economy. The ratio against national GDP allows for a comparison of countries irrespective their economic size.
Definition	Number of economic agents over GDP
Unit of measurement	Number of agents / billion € (ratio)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	-
Data source(s)	For number of agents: JRC AI TES Dataset. For GDP: OECD See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	GDP at regional level is not available for all worldwide regions. It is available, at least for EU regions (NUTS2)
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

3.1.2 AI areas of strength

Indicator name	***G3: Comparative advantage in AI areas***
Rationale	It explores the specialisation of geographic areas in the AI field. It measures a country's specialisation in a thematic area (or AI subdomain) within the AI domain in comparison with the world average specialisation in that area.
Definition	The Revealed Comparative Advantage (RCA) is a ratio computed as the share of activities of a geographic area in a thematic area over the share of activities in that thematic area worldwide. For the computation, activities are assigned to the thematic area that better represents the activity's content.
Unit of measurement	Ratio
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Thematic areas: Machine learning, Computer vision, AI services…
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	The collected activities must contain text to be considered in this indicator.
References and Comments	The value RCA = 1 represents the world average or average specialisation in the thematic area when all countries are considered. It is the benchmark towards which all countries are compared. When a country presents RCA>1 in a thematic area, then this country is relatively specialised in this area and has a revealed comparative advantage. *As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***G4: AI thematic hotspots***
Rationale	It measures national or regional performance globally on each AI thematic area or subdomain, in terms of number of R&D and industrial AI activities. This indicator shows the intensity of a country's or a region's participation in a thematic area compared to all countries or regions globally.
Definition	Distribution of activities of a thematic area by geographic area: Number of activities of a geographic area in a thematic area, over number of worldwide (or EU) activities in that same thematic area.
Unit of measurement	Number of activities (percentage)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Thematic areas: Machine learning, Computer vision, AI services…
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	The collected activities must contain text to be considered in this indicator.
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***G5: Comparative advantage in robotics' trade***
Rationale	It is an indicators traditionally used to identify strengths in world comparisons, applied in this case to trade activity.
Definition	The Revealed comparative Advantage (RCA) is a ratio computed as the share of trade activity of a geographic area over the share of trade activity worldwide.
Unit of measurement	Imports and exports (volume and value)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	
Data source(s)	UN Comtrade It is a publicly available repository of official international trade statistics and relevant analytical tables.
Reference date	Several years
Reporting frequency	Annual
Known limitations	At a very disaggregated level, trade data may present a high percentage of missing information. If imputations are needed, this may generate concerns depending on the methodology used
References and Comments	
Foreseen availability	Mid 2021

3.1.3 AI investments

Indicator name	*G6: AI investments*
Rationale	A sufficient and continued level of investments is crucial to support the development and uptake of AI throughout Europe. This indicator provides an estimation of AI investments by public and private organisations at country level.
Definition	In absence of reliable data on the level of AI investments by the private and public sector, AI Watch has developed a comprehensive methodology to estimate AI investments for the EU and its Member States. In this framework, AI investments include: expenditures on labour and skills as well as tangible and intangible capital assets incurred by public and private organizations to develop and implement AI to (re-)design business processes in order to create new or improve existing products or services.
Unit of measurement	Real values (Euro)
Geographical coverage	EU27, UK
Geographical granularity	Country
Breakdown	Type of expenditure: AI-related expenditures on education programmes, compensation of AI ICT specialists, AI-related corporate training, R&D, product design, brand, organisational capital ICT software and hardware, telecommunications equipment and data. Public and private sector.
Data source(s)	JRC estimates for AI Watch based on multiple sources
Reference date	2018, 2019
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	*As long as the estimation is updated with this frequency. Reference: Nepelski, D., and Sobolewski, M., Estimating investments in General Purpose Technologies. The case of AI Investments in Europe, EUR 30072 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-10233-5, doi:10.2760/506947, JRC118953. https://ec.europa.eu/jrc/en/publication/estimating-investments-general-purpose-technologies-case-ai-investments-europe
Foreseen availability	Mid 2021

3.2 Industry [I]

3.2.1 Industry

Indicator name	***I1: AI firms' profile***
Rationale	It measures the level of industrial involvement of a geographical area in the worldwide AI landscape and compares the different firm demographic profiles of AI firms.
Definition	Number of firms in the ecosystem. Distribution of firms categorised by age, size, industry sector and AI-business type.
Unit of measurement	Number of firms (integer), percentage for breakdowns
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Firm demographics: Industrial sector, Size class, Age group; and core-business type
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	Breakdown by firm demographics is limited to the subset of firms for which there is available data in the sources. Coverage varies depending on the macro area, with Asian countries more poorly covered. Population data is inferred based on this subset.
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***I2: Robotics start-ups***
Rationale	This indicator provides insights about the vitality of this sector in which Europe outstands, providing hints on potential shifts in worldwide leadership and competition landscape.
Definition	Number of new robotic start-ups by year
Unit of measurement	Number of companies
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Firms' categories
Data source(s)	Dealroom It is a private data provider on startups, growth companies and tech ecosystems in Europe and worldwide.
Reference date	Several years
Reporting frequency	Annual
Known limitations	The database does not have full coverage of worldwide start-ups, so it may provide an incomplete picture
References and Comments	
Foreseen availability	Mid 2021

3.3 Research and Development [R]

3.3.1 R&D activity

Indicator name	***R1: AI economic agents in AI R&D***
Rationale	It captures the presence of economic agents involved in the development of AI. The distinction by organisation type enables the analysis of the institutional profile of the key players in the technological advances and innovative activities in the domain, and the assessment of the overall propensity of firms and research institutions to be active in AI R&D activities.
Definition	Distribution of economic agents involved in AI-related R&D activities. The R&D activities considered are: (i) patent applications, (ii) "frontier research" publications (i.e., publication in top AI journals and conferences), and (iii) EU-funded projects (only when analysing the EU focus, to avoid an EU-centric biased view).
Unit of measurement	Number of agents (integer)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Organisation type: research institute, firm or governmental institution. Type of R&D activity: patent applications, frontier research publications, EU-funded projects FP7-H2020 (where relevant)
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***R2: AI R&D Activity score***
Rationale	It assesses the level of involvement in AI-related R&D, by weighting the presence of AI economic agents in a geographic area with the amount of AI activity they develop.
Definition	Number of R&D activities developed by agents, computed as the sum of the fractional count for all the economic agents included in a geographical area. To account for collaboration in the same activity by several economic agents, the fractional count of the activity corresponding to one economic agent is computed as 1 over the number of participating agents in that activity. The sum of all fractions adds up to 1.
Unit of measurement	Real positive number
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Type of R&D activity: patent applications, frontier research publications, and EU-funded projects FP7-H2020 (where relevant)
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***R3: Intensity of AI research activity***
Rationale	Activity level or intensity for particular AI tasks measured in terms of the production (e.g., outputs such as research publications, results) from the AI community. Tasks (and specific benchmarks) that have increasing trends in their production rates –not their performance metrics– may indicate that more AI researchers and practitioners are working on them (i.e., there is a clear research effort and intensity). Note that this is not an indication of progress, although, presumably, effort may eventually lead to progress.
Definition	In order to calculate the intensity in each AI tasks (e.g., Image Classification, Face Recognition, Speech Recognition, Text Summarisation, etc.) we sum the number of publications (or results) related to a particular task over a period of time. Note that the number of publications/results may be normalised to sum up to 100% per year across all AI tasks analysed.
Unit of measurement	Number of publications (percentage, normalised in [0,1])
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	The indicator may be aggregated and summarised by AI tasks (e.g., Image Classification, Facial Recognition, Speech Recognition, etc.) or specific benchmarks belonging to a particular task (e.g., Imagenet, COCO, CIFAR-10, etc., for Image Classification).
Data source(s)	AIcollaboratory (http://www.aicollaboratory.org/) It is an open data repository which incorporates different sources of information regarding intelligent systems and approaches, behavioural tests, results and measurements, constructs of intelligence, etc., which aims to develop a collaborative initiative for the analysis, evaluation, comparison and classification of AI systems.
Reference date	Year, from 2017 to 2020
Reporting frequency	Annual
Known limitations	Not all the AI tasks can be evaluated for the whole period (2010-2020).
References and Comments	References: Barredo, P., Hernandez-Orallo, J., Martínez-Plumed, F. and O Heigeartaigh, S., "The Scientometrics of AI Benchmarks: Unveiling the Underlying Mechanics of AI Research", 1st International Workshop on Evaluating Progress in Artificial Intelligence (EPAI 2020) @ ECAI 2020, Santiago de Compostela, Spain, September 4, 2020. http://dmip.webs.upv.es/EPAI2020/papers/EPAI_2020_paper_12.pdf Martínez-Plumed, F., Hernández-Orallo, J., Gómez, E., "Tracking AI: The Capability is (Not) Near", Proceedings of the 24th European Conference on Artificial Intelligence (ECAI 2020), Santiago de Compostela, Spain, September 2020. https://ecai2020.eu/papers/1009_paper.pdf
Foreseen availability	April 2021

3.3.2 Network of collaborations

Indicator name	***R4: AI R&D collaborating regions***
Rationale	It measures how much a region is able to develop a network of collaborations with other regions (within the country or external).
Definition	Number of regions with which there are AI-related R&D collaborations
Unit of measurement	Number of regions (integer)
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Potential additional breakdown: Type of R&D activity: patent applications, frontier research publications, and EU-funded projects FP7-H2020 (where relevant)
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***R5: Peer-to-peer collaborations***
Rationale	It measures how many collaborations are developed by agents of a geographical area
Definition	Number of weighted collaborations developed by economic agents. The weight is based on the fractional count. As collaborations are considered as "peer-to-peer" collaborations, each collaboration has a weight that equals one divided by the binomial coefficient determined with n=number of players involved in the activity, and k=2.
Unit of measurement	Real positive number
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Profile of collaborating agents, as a combination of type of agent (firm, research, government) and location of agents (local, abroad): B2B local: collaborations between local firms, B2B abroad between local firms and firms abroad, B2R local: between local firms and local research institutes, R2R local: between research institutes and local research institutes, G2B local: between local gov. institutions and local firms. Potential additional breakdown: Type of R&D activity: patent applications, frontier research publications, and EU-funded projects FP7-H2020 (where relevant).
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	*As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

Indicator name	***R6: Strategic position in the network of collaborations***
Rationale	It assesses the strategic position of the geographical area in the AI R&D network of collaborations, and hence its influential capacity.
Definition	Weighted Betweenness Centrality, normalised in the interval [0,1], in the overall R&D Network. To determine the weight of collaborations, the fractional count is considered. As the network is a geo-based network, initially determined by the peer-to-peer collaborations of players (which are considered depending on their location), each collaboration has a weight that equals one divided by the total number of one-to-one connections that can be established among all the collaborating players. The number of one-to-one connection is given by the binomial coefficient determined with n=number of players involved in the activity, and k=2.
Unit of measurement	Real positive number
Geographical coverage	World
Geographical granularity	World, Macro area (top countries plus world regions), Country, Region
Breakdown	Potential additional breakdown: Type of R&D activity: patent applications, frontier research publications, and EU-funded projects FP7-H2020 (where relevant).
Data source(s)	JRC AI TES Dataset See description of the dataset in indicator G1.
Reference date	Period 2009-2020 (one value for the entire period)
Reporting frequency	Annual* (see References and Comments)
Known limitations	
References and Comments	We chose Betweenness centrality instead of other centrality measures, such as, e.g. Closeness, due to the interest in showing R&D hubs. Closeness centrality is a measure related to efficiency, as it measures the ability of a node to be directly connected with the rest of the network. As we consider R&D activities, in which the circulation of information is the key point for the creation of innovation, betweenness is more able to reveal where the important hubs are located. In fact, betweenness is related to the ability of being in a crucial position, i.e., having a key role in "connecting" nodes, which implies to be able to "control" exchanges between other nodes. *As long as JRC TES AI Dataset is updated with this frequency. Reference: Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106. https://publications.jrc.ec.europa.eu/repository/handle/JRC120106
Foreseen availability	April 2021

3.4 Technology [T]

3.4.1 Technological enablers

Indicator name	***T1: AI in APIs***
Rationale	It measures the adoption of AI in Application programming interfaces (APIs). APIs are computing interfaces that define interactions between multiple software (intermediaries). Most of the applications today are built with APIs and their number is continuously increasing, including its use by government bodies. APIs are relevant to share data related to government policies in specific high value domains, as requested by the recent Open Data directive. ProgrammableWeb (PW) is the most popular open APIs repository in the world. In 2017, PW contained 21609 APIs, 1641 libraries, 15329 SDKs, 7629 mashups, and 10989 sample source codes. By measuring adoption of AI in APIs, we indirectly capture the adoption of AI in (web) software.
Definition	Number of AI-related Input/Output APIs that have been declared into the ProgrammableWeb catalogue. APIs are used either by AI applications (input) or provide AI functionalities (output)
Unit of measurement	Number of records
Geographical coverage	World
Geographical granularity	World
Breakdown	By AI keyword, by AI domains, by technology (not only API, but also SDK, mashups --> apps).
Data source(s)	JRC ProgrammableWeb (PW) database (APIs4DGov) It is a repository of web APIs, mashups, and applications.
Reference date	2005-2017; from 2018 onwards (one value per year)
Reporting frequency	Annual* (see References and Comments)
Known limitations	The PW database is mainly filled by US developers, it is a volunteering-based catalogue. In 2018, the DB content has been cleaned and clustered, causing a break in the series. The historical series can be computed in the period 2005-2017 and from 2018 onwards.
References and Comments	*As long as the private dataset remains available. Reference: Delipetrev, B., Kostic, U. and Vaccari, L., 'Tracking of artificial intelligence adoption in ProgrammableWeb directory', 1st International Workshop on Evaluating Progress in Artificial Intelligence - EPAI 2020, 24th European Conference on Artificial Intelligence - ECAI 2020, Santiago de Compostela, Spain, 2020 http://dmip.webs.upv.es/EPAI2020/papers/EPAI_2020_paper_2.pdf (accessed 20 November 2020).
Foreseen availability	Mid 2021

3.4.2 Performance of AI

Indicator name	*T2: Performance of AI research*
Rationale	Performance levels for particular AI tasks are measured in terms of different evaluation metrics (accuracy, AUC, EM, F1, BLEU score, etc.) depending on the tasks at hand. Performance metrics may be used as a proxy indicator of progress.
Definition	In order to calculate the performance in each AI tasks (e.g., Image Classification, Face Recognition, Speech Recognition, Text Summarisation, etc.) we average the performance results (when common evaluation metrics are used) related to a particular task over a period of time.
Unit of measurement	Average results in the units required by the evaluation metric (e.g., percentage in [0,1] for accuracy-related metrics)
Geographical coverage	World
Geographical granularity	World
Breakdown	The indicator may be aggregated and summarised by AI tasks (e.g., Image Classification, Facial Recognition, Speech Recognition, etc.) or specific benchmark belonging to a particular tasks (e.g., Imagenet, COCO, CIFAR-10 for Image Classification). It is not possible to talk about "aggregated" progress as we are using different dimensions, data, goals, etc.
Data source(s)	AIcollaboratory (http://www.aicollaboratory.org/) See description of the dataset in indicator R3.
Reference date	2017-2020 (one value per year)
Reporting frequency	Annual
Known limitations	Not all the AI tasks can be evaluated for the whole period (2010-2020). Different AI tasks are evaluated using different evaluation metrics making it difficult to compare results among them.
References and Comments	References: Barredo, P., Hernandez-Orallo, J., Martínez-Plumed, F. and O Heigeartaigh, S., "The Scientometrics of AI Benchmarks: Unveiling the Underlying Mechanics of AI Research", 1st International Workshop on Evaluating Progress in Artificial Intelligence (EPAI 2020) @ ECAI 2020, Santiago de Compostela, Spain, September 4, 2020. http://dmip.webs.upv.es/EPAI2020/papers/EPAI_2020_paper_12.pdf Martínez-Plumed, F., Hernández-Orallo, J., Gómez, E., "Tracking AI: The Capability is (Not) Near", Proceedings of the 24th European Conference on Artificial Intelligence (ECAI 2020), Santiago de Compostela, Spain, September 2020. https://ecai2020.eu/papers/1009_paper.pdf
Foreseen availability	April 2021

3.4.3 Standardisation

Indicator name	***T3: Standardisation activity engagement***
Rationale	Standardisation activities enable interoperability and foster innovation, efficiency and growth.
Definition	Number and maturity level of standardization initiatives, and the countries engaged in them
Unit of measurement	Number of activities
Geographical coverage	World
Geographical granularity	World, Country
Breakdown	Maturity level
Data source(s)	JRC estimates for AI Watch based on existing worldwide standardisation initiatives.
Reference date	2020
Reporting frequency	Annual
Known limitations	
References and Comments	
Foreseen availability	April 2021

3.5 Societal aspects [S]

3.5.1 Diversity in research

Indicator name	***S1: Gender diversity index***
Rationale	We measure diversity in the AI field, to track the representation of female researchers in the field and the impact of gender equality policies. This indicator measures Gender diversity of a certain conference and makes an average over most relevant AI conferences.
Definition	The diversity indices originate from the study of biodiversity of species in an environment. We consider three different *species* (S = 3) in the gender dimension: "male", "female" and "other". We compute Shannon evenness by means of the Pielou diversity index. For calculating the Gender Diversity Index, we consider three different communities: keynotes (k), authors (a) and organisers (o). Our final GDI performs a weighted average among the Pielou index in each community with the following weights: 1/2 for keynotes, 1/3 for authors and 1/5 for organizers.
Unit of measurement	[0, 1] from less to more heterogeneous/diverse
Geographical coverage	World
Geographical granularity	World
Breakdown	This indicator is measured for each scientific conference. We might aggregate over conferences in a given year using statistics such as the average or the standard deviation, or select only few relevant conferences such as ICML, NeurIPS.
Data source(s)	divinAI.org DivinAI (Diversity in Artificial Intelligence) is an initiative of the HUMAINT project at Joint Research Centre (EC) and the ICT Department at Pompeu Fabra University, Barcelona. The goal of DivinAI is to research and develop a set of diversity indicators, related to Artificial Intelligence developments, with special focus on gender balance, geographical representation and presence of academia vs companies. The collaborative website collects data on keynote speakers, members of the organisation committee and authors from the most relevant AI conferences worldwide:
Reference date	2017-2020 (one value per year)
Reporting frequency	Annual
Known limitations	These diversity indexes are computed for each conference.
References and Comments	Reference: Freire, A., Porcaro, L., and Gómez, E., Measuring Diversity of Artificial Intelligence Conferences. https://arxiv.org/abs/2001.07038
Foreseen availability	April 2021

Indicator name	***S2: Geographic diversity index***
Rationale	We measure diversity in the AI field, to track the representation of researchers from different geographical locations in the research field and the impact of some inclusion policies. This indicator represents the geographic diversity (per continent) in AI conferences . It is possible to compute an average indicator for major AI conferences in a given year.
Definition	The diversity indices originate from the study of biodiversity of species in an environment. We consider as *species* the seven different continents (Asia, Africa, North America, South America, Antarctica, Europe, and Australia). We compute the Shannon Index for each of the following communities: keynotes (k), authors (a) and organizers (o). We then weight each community using the following weights: 1/2 for keynotes, 1/3 for authors and 1/5 for organizers.
Unit of measurement	[0, 1] from less to more heterogeneous/diverse
Geographical coverage	World
Geographical granularity	World, Continent
Breakdown	This indicator is measured for each scientific conference
Data source(s)	divinAI.org See description of the dataset in indicator S1.
Reference date	2017-2020 (one value per year)
Reporting frequency	Annual
Known limitations	These diversity indexes are computed for each conference.
References and Comments	Reference: Freire, A., Porcaro, L., and Gómez, E., Measuring Diversity of Artificial Intelligence Conferences. https://arxiv.org/abs/2001.07038
Foreseen availability	April 2021

Indicator name	***S3: Business diversity index***
Rationale	We measure diversity in the AI field, to track the representation of researchers from academia vs industry in the research field.
Definition	The diversity indices originate from the study of biodiversity of species in an environment. We consider three different *species* (S = 3) in the business dimension: ”academia”, ”industry” and ”research centre”. We compute Shannon evenness by means of the Pielou diversity index. For calculating the Gender Diversity Index, we consider three different communities: keynotes (k), authors (a) and organisers (o). Our final GDI performs a weighted average among the Pielou index in each community with the following weights: 1/2 for keynotes, 1/3 for authors and 1/5 for organizers.
Unit of measurement	[0, 1] from less to more heterogeneous/diverse
Geographical coverage	World
Geographical granularity	World
Breakdown	This indicator is measured for each scientific conference
Data source(s)	divinAI.org See description of the dataset in indicator S1.
Reference date	2017-2020 (one value per year)
Reporting frequency	Annual
Known limitations	These diversity indexes are computed for each conference.
References and Comments	Reference: Freire, A., Porcaro, L., and Gómez, E., Measuring Diversity of Artificial Intelligence Conferences. https://arxiv.org/abs/2001.07038
Foreseen availability	April 2021

Indicator name	***S4: Conference diversity index***
Rationale	Combined conference diversity index
Definition	This index is computed by the combination of gender, geographic and business indexes using the following formula: CDI = 1/3 *(GDI + GeoDI/2 + BDI)
Unit of measurement	[0, 1] from less to more heterogeneous/diverse
Geographical coverage	World
Geographical granularity	World
Breakdown	This indicator is measured by each scientific conference
Data source(s)	divinAI.org See description of the dataset in indicator S1.
Reference date	2017-2020 (one value per year)
Reporting frequency	Annual
Known limitations	These diversity indexes are computed per each conference.
References and Comments	Reference: Freire, A., Porcaro, L., and Gómez, E., Measuring Diversity of Artificial Intelligence Conferences. https://arxiv.org/abs/2001.07038
Foreseen availability	April 2021

3.5.2 Higher education

Indicator name	***S5: AI in university programmes***
Rationale	It indicates the intensity with which AI is included in official curricula, as a proxy of supply of AI capacities
Definition	Proportion of programmes with AI content over total number of programmes
Unit of measurement	Number of programmes (percentage)
Geographical coverage	EU27, United Kingdom, Norway, Switzerland, Canada, United States, Australia
Geographical granularity	Country
Breakdown	By level of study (bachelor and master), by field of education (ISCED-F2013)
Data source(s)	JRC PREDICT's Education offer Dataset It is a dataset of university programmes addressing advanced digital technologies, including artificial intelligence. It collects information on the programmes (education level, field of education, domain specific areas taught…) and the institutions offering them (name and location of the higher-education institution).
Reference date	2019-20 academic year
Reporting frequency	Annual* (see References and Comments)
Known limitations	Based on courses taught in English: non-English speaking countries have a lower representation.
References and Comments	This indicator could be linked with indicators on the demand side. Reference: Righi, R., López-Cobo, M., Alaveras, G., Samoili, S., Cardona, M.., Vázquez-Prada Baillet, M., Ziemba, L.W., and De Prato, G., Academic offer of advanced digital skills in 2019-20. International comparison. Focus on Artificial Intelligence, High Performance Computing, Cybersecurity and Data Science, EUR 30351 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21541-9, doi:10.2760/225355, JRC121680. https://publications.jrc.ec.europa.eu/repository/handle/JRC121680
Foreseen availability	April 2021

Indicator name	***S6: University places with AI content***
Rationale	It provides an estimation of the potential future workforce trained with AI skills in specific AI domain.
Definition	Number of available places in university programmes with AI content by AI domain (ML, AI ethics, Robotics, Computer vision…)
Unit of measurement	Number of places
Geographical coverage	EU27, United Kingdom, Norway
Geographical granularity	Country
Breakdown	By level of study (bachelor and master) AND field of education (ISCED-F2013)
Data source(s)	JRC PREDICT's Education places Dataset Estimations based on multiple sources.
Reference date	2019-20 academic year
Reporting frequency	Annual* (see References and Comments)
Known limitations	This indicator only measures the part of workforce who gained capabilities in formal education
References and Comments	This indicator could be linked with indicators on the demand side: number of job places advertised by companies. Reference: Gómez Losada, Á., López-Cobo, M., Samoili, S., Alaveras, G., Vázquez-Prada Baillet, M., Cardona, M., Righi, R., Ziemba, L., and De Prato, G., Estimation of supply and demand of tertiary education places in advanced digital profiles in the EU. Focus on Artificial Intelligence, High Performance Computing, Cybersecurity and Data Science, EUR30377EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-22281-1, doi:10.2760/559530, JRC121683. https://publications.jrc.ec.europa.eu/repository/handle/JRC121683
Foreseen availability	April 2021

Indicator name	***S7: AI intensity in university places***
Rationale	It provides a measure on the size of potential future workforce trained with AI skills.
Definition	Proportion of available places in university programmes with AI content over total number of places in university programmes
Unit of measurement	Number of places (percentage)
Geographical coverage	EU27, United Kingdom, Norway
Geographical granularity	Country
Breakdown	By level of study (bachelor and master) AND field of education (ISCED-F2013)
Data source(s)	JRC PREDICT's Education places Dataset Estimations based on multiple sources.
Reference date	2019-20 academic year
Reporting frequency	Annual* (see References and Comments)
Known limitations	This indicator only measures the part of workforce who gained capabilities in formal education
References and Comments	This indicator could be linked with indicators on the demand side: number of job places advertised by companies. Reference: Gómez Losada, Á., López-Cobo, M., Samoili, S., Alaveras, G., Vázquez-Prada Baillet, M., Cardona, M., Righi, R., Ziemba, L., and De Prato, G., Estimation of supply and demand of tertiary education places in advanced digital profiles in the EU. Focus on Artificial Intelligence, High Performance Computing, Cybersecurity and Data Science, EUR30377EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-22281-1, doi:10.2760/559530, JRC121683. https://publications.jrc.ec.europa.eu/repository/handle/JRC121683
Foreseen availability	April 2021

3.6 AI in the Public sector [P]

3.6.1 Public procurement

Indicator name	***P1: Public values in EU public procurement***
Rationale	It provides information about the inclusion of European/Public values in AI procurement in the public sector.
Definition	Frequency with which European/public values, e.g. transparency or sustainability, are considered in the award criteria of AI public procurement contracts.
Unit of measurement	Procurement award criteria
Geographical coverage	EU27, UK, NO, CH, EU accession countries
Geographical granularity	Country, Region
Breakdown	By project (AI application), country, public administration (at different levels).
Data source(s)	TED TED (Tenders Electronic Daily) is the online version of the 'Supplement to the Official Journal' of the EU, dedicated to European public procurement. TED publishes procurement award notices, including calls for tenders.
Reference date	2014-20 (one value per year)
Reporting frequency	Irregular
Known limitations	It has the same limitations as the data source (e.g. it includes public procurement only above a certain threshold, it does not include AI developed in-house by the public sector, etc.). Covering only a part of the AI 'puzzle'.
References and Comments	This is proposed as a new and experimental indicator. Defining the methodology requires further study.
Foreseen availability	End 2021

Indicator name	***P2: Entrepreneurship for the public sector***
Rationale	It provides an overview of commercial operators providing AI solutions to the public sector.
Definition	Commercial operators as providers of AI solutions to the public sector.
Unit of measurement	Number and profile of agents
Geographical coverage	EU27, UK, NO, CH, EU accession countries
Geographical granularity	Country
Breakdown	By country (headquarters and place of operation), by type of enterprise (SME or not).
Data source(s)	TED See description of the dataset in indicator P1.
Reference date	2014-20 (one value per year)
Reporting frequency	Irregular
Known limitations	It has the same limitations as the data source (e.g. it includes public procurement only above a certain threshold, it does not include AI developed in-house by the public sector, etc.). Covering only a part of the AI 'puzzle'.
References and Comments	This is proposed as a new and experimental indicator. Defining the methodology requires further study.
Foreseen availability	End 2021

Indicator name	***P3: Investments by the public sector's procurement***
Rationale	It provides information about AI investments in the public sector through procurement of goods and services.
Definition	AI investments in the public sector through procurement (capital costs).
Unit of measurement	Euro
Geographical coverage	EU27, UK, NO, CH, EU accession countries
Geographical granularity	Country, Region
Breakdown	By project (AI application), by public administration (at different levels), by commercial operator; by AI technology.
Data source(s)	TED See description of the dataset in indicator P1.
Reference date	2014-20 (one value per year)
Reporting frequency	Irregular
Known limitations	It has the same limitations as the data source (e.g. it includes public procurement only above a certain threshold, it does not include AI developed in-house by the public sector, etc.). Covering only a part of the AI 'puzzle'.
References and Comments	This is proposed as a new and experimental indicator. Defining the methodology requires further study.
Foreseen availability	End 2021

3.6.2 AI patents for the Public sector

Indicator name	***P4: Patents for the public sector***
Rationale	It provides information about (future developments in) AI technologies, their providers, the areas of application
Definition	AI patents aimed specifically at the public sector
Unit of measurement	Number of patents
Geographical coverage	World
Geographical granularity	Country, Region
Breakdown	By AI technique, by AI application, by operator, etc.
Data source(s)	WIPO, EPO PATSTAT WIPO offers data on the intellectual property system PATSTAT contains bibliographical and legal event patent data from leading industrialised and developing countries.
Reference date	2011-2019 (one value per year)
Reporting frequency	Annual
Known limitations	Not all AI solutions are patented. Not all relevant elements of AI are patentable (algorithms on their own are not patentable, only when they are part of an innovation; some/most software are not patentable in most markets).
References and Comments	Patent analysis is a standard tool. Defining the elements of analysis/data collection relevant to AI in the public sector requires further study.
Foreseen availability	End 2021

4 Conclusions

The AI Watch knowledge service monitors the evolution and take up of AI, focusing on Europe but also reflecting on the global view. AI Watch considers impacts of AI at different levels and in different domains: from business to research and development, from take up in different sectors to technological development in the AI domain itself, from changes in industrial robotics to emergence and spread of new types of AI based services to citizens, etc. These are some of the aspects to be considered with the objective of providing an independent assessment of the impacts and benefits of AI on growth, employment, education, and society.

In order to support policy decisions, evidence has to be collected, organised and analysed in order to build suitable indicators. This report proposes an AI Watch Index that covers the main aspects characterising the evolution an development of AI, and that allows to investigate the relative position of Europe in the global landscape. The proposed AI Watch Index is composed by 28 indicators, organised along six dimensions: Global view on the AI ecosystem, Industry, Research and Development, Technology, Societal aspects, and AI in the Public sector. The 28 indicators, documented with a metadata fiche, are identified by screening AI Watch activities to show a relevant, useful, and scientifically sound picture of AI in Europe. They are selected following quality criteria regarding, e.g., clear definition, time series availability, geographical coverage.

The next steps include the systematic collection of data for each indicator, the online presentation of the index in the AI Watch portal, together with suitable visualisations. To facilitate usability, interpretation and replicability, the online dissemination of the indicators will be accompanied by individual fiches including the detailed description of each indicator, as presented in this report. Additional indicators may be considered useful and pertinent to be added in future editions of the index.

References

Barredo, P., Hernandez-Orallo, J., Martínez-Plumed, F. and O Heigeartaigh, S., " The Scientometrics of AI Benchmarks: Unveiling the Underlying Mechanics of AI Research", 1st International Workshop on Evaluating Progress in Artificial Intelligence (EPAI 2020) @ ECAI 2020, Santiago de Compostela, Spain, September 4, 2020.

Benaich, N. and Hogarth, I. "State of AI Report 2020", https://www.stateof.ai/ (accesed 30/11/2020)

Delipetrev, B., Kostic, U. and Vaccari, L., 'Tracking of artificial intelligence adoption in ProgrammableWeb directory', 1st International Workshop on Evaluating Progress in Artificial Intelligence - EPAI 2020, 24th European Conference on Artificial Intelligence - ECAI 2020, Santiago de Compostela, Spain, 2020

European Commission (2018a), Artificial Intelligence for Europe, COM(2018) 237 final.

European Commission (2018b), Coordinated Plan on Artificial Intelligence, COM(2018) 795 final.

Gómez Losada, Á., López-Cobo, M., Samoili, S., Alaveras, G., Vázquez-Prada Baillet, M., Cardona, M., Righi, R., Ziemba, L., and De Prato, G., Estimation of supply and demand of tertiary education places in advanced digital profiles in the EU. Focus on Artificial Intelligence, High Performance Computing, Cybersecurity and Data Science, EUR30377EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-22281-1, doi:10.2760/559530, JRC121683

Martínez-Plumed, F., Hernández-Orallo, J., Gómez, E., "Tracking AI: The Capability is (Not) Near", Proceedings of the 24th European Conference on Artificial Intelligence (ECAI 2020), Santiago de Compostela, Spain, September 2020.

Nepelski, D., and Sobolewski, M., Estimating investments in General Purpose Technologies. The case of AI Investments in Europe, EUR 30072 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-10233-5, doi:10.2760/506947, JRC118953.

Righi, R., López-Cobo, M., Alaveras, G., Samoili, S., Cardona, M.., Vázquez-Prada Baillet, M., Ziemba, L.W., and De Prato, G., Academic offer of advanced digital skills in 2019-20. International comparison. Focus on Artificial Intelligence, High Performance Computing, Cybersecurity and Data Science, EUR 30351 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21541-9, doi:10.2760/225355, JRC121680.

Samoili S., Righi R., Cardona M., López Cobo M., Vázquez-Prada Baillet M., and De Prato G., TES analysis of AI Worldwide Ecosystem in 2009-2018, EUR 30109 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-16661-0, doi:10.2760/85212, JRC120106.

USAID, Recommended Performance Indicator Reference Sheet (PIRS). Guidance & Template. Updated 09/07/2016. https://usaidlearninglab.org/library/recommended-performance-indicator-reference-sheet (accesed 3/09/2019)

Von Schirnding, Y., Health in sustainable development planning: The role of indicators, 2002, World Health Organization, Geneva.

Zhang, D., Mishra, S., Brynjolfsson E., Etchemendy, J., Ganguli, D., Grosz, B., Lyons, T., Manyika, J., Niebles, J.C., Sellitto, M., Shoham, Y., Clark, J., and Perrault, R., "The AI Index 2021 Annual Report," AI Index Steering Committee, Human-Centered AI Institute, Stanford University, Stanford, CA, March 2021.

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Annexes

Annex 1. Definitions and Criteria for indicator selection

Box 1. Definition of main concepts

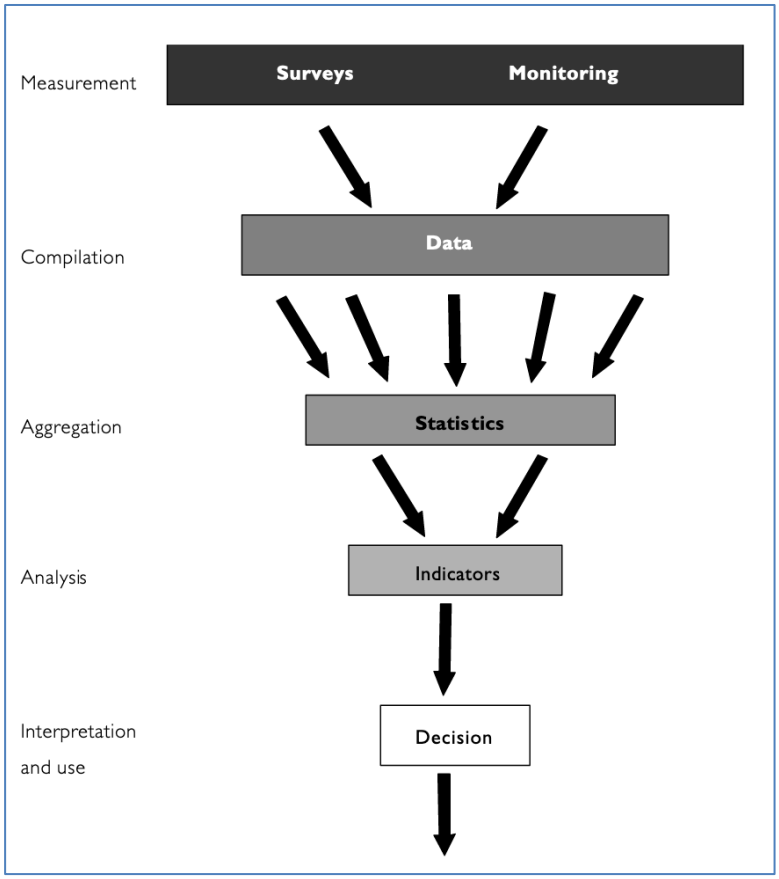
A **statistical indicator** is the representation of statistical data for a specified time, place or any other relevant characteristic, corrected for at least one dimension (usually size) so as to allow for meaningful comparisons. It is a summary measure related to a key issue or phenomenon and derived from a series of observed facts. Indicators can be used to reveal relative positions or show positive or negative change. They allow comparisons over time or across territories. Numerous indicators can be aggregated into an index. Source: Eurostat's Glossary.

A **variable** is a characteristic of a unit being observed that may assume more than one of a set of values to which a numerical measure or a category from a classification can be assigned (e.g. income, age, weight, etc., and "occupation", "industry", "disease", etc.). Source: OECD Glossary of Statistical Terms.

Values are all the possible realisations of a variable. E.g.: for age: 0 to 130. Source: derived from OECD Glossary of Statistical Terms.

Data refer to characteristics or information, usually numerical, that are collected through observation. Data are typically the results of measurements and can be visualised using graphs or images. Source: Eurostat's Glossary.

Figure 4 – Workflow of indicator computation for decision making



Source: Von Schirnding, 2002.

Box 2. General criteria for indicators

Indicators should be:

Generally relevant

- Related to a specific question or issue of concern
- Sensitive to changes in the dimension under measurement
- Give early warning of changes

Scientifically sound

- Unbiased and representative of the issue in question
- Scientifically credible, reliable and valid
- Based on the best available data of acceptable quality
- Robust and unaffected by minor changes in the method or scale used in their construction
- Consistent and comparable over time and space

Applicable to users

- Relevant to policy and management needs
- Based on data that are available or can be collected or monitored with a reasonable financial/time resource input
- Easily understood and applied by potential users
- Acceptable to stakeholders

Source: modified from Von Schirnding (2002).

Box 3. Criteria for indicators of use for international purposes

These indicators should be:

- Appropriate for inter-country comparisons
- Relevant to international initiatives
- Attractive to a range of sectors, partners and institutions
- Ideally usable for decision-making at different tiers of government
- Based on sound, internationally comparable data that are readily available or easily and relatively inexpensively collected

Source: modified from Von Schirnding (2002).

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