November 2018 · Dr. Stefan Heumann with Nicolas Zahn

Benchmarking National AI Strategies

Why and how indicators and monitoring can support agile implementation

Stiftung Neue Verantwortung

Think Tank für die Gesellschaft im technologischen Wandel

Content

Introduction

Artificial Intelligence (AI) is considered to be the key technology for the 21st century. Many countries have adopted national AI strategies in order to take advantage of the opportunities of AI and to address important challenges. The German government has also followed suit and formally adopted and published its own national strategy in November 2018.[1] Like many other AI strategies, the German government takes a comprehensive approach, covering implications of AI for research, transfer between research and business development, employment, education, and regulation to name just a few of the most important issue areas. However, the strategy has been criticized for not defining clear and measurable objectives. The lack of concrete goals and clear indicators of success is symptomatic of many strategy papers and announcements in German digital policy. Definitions of clear goals are missing as well as policies to monitor progress and measure success. Politicians and citizens are therefore often left wondering what precisely we are trying to achieve, when it will be achieved, and whether we are making progress. The government's AI strategy provides the opportunity to do better this time. The advantages are clear. Defining indicators requires the development of cross-departmental goals, which lays the foundation for tracking progress and thus creates the conditions for an effective implementation of the strategy.

A broad debate about AI is urgently needed, due to the broad and imprecise use of the term in public discourse. Even in political discourse, it is generally unclear what is meant by "AI". When defining certain goals, for example the increase of AI-associated professorships in German higher education, it is important to understand when a professor's work can be characterized as rooted in AI and when this is not the case. The same holds for research funding or increasing the numbers of AI-driven startups. However, it is not only the clear definition of goals that necessarily leads to a deeper engagement with the concept of AI and the technologies that this term covers. The question of how to define achievement indicators and measure progress is also important. Discussing the definition of AI also puts us in the position to better understand what a strong AI ecosystem is and how we can empirically measure its current state as well as track its further development.

Such an examination of goals, benchmarks and indicators must always be critical in nature. Meeting benchmarks and scoring high on certain indi-

1 https://www.bundesfinanzministerium.de/Content/DE/Downloads/Digitalisierung/2018-11-15-Strategie-zur-Kuenstlichen-Intelligenz.pdf?__blob=publicationFile&v=2

cators should never be an end in itself. We should rather continuously question whether the indicators really measure what we want measured, and whether potential flaws in our indicators, data sources or analysis could be distorting the picture. For some questions, it may be difficult or even impossible to verify progress and goal attainment through easily observable indicators. Flaws in data sources and the limits of our analytical methods must be recognised and openly discussed – a discussion that we seek to stimulate through this paper. That said, these limits are no justification for avoiding such a debate. The benefits clearly outweigh the problems. Benchmarks and indicators enable agile political governance that is based on the definition and measurement of progress and success.

We differentiate the definition of political measures and success criteria as input- and output-indicators. Before one can develop these, the overarching goals need to be defined. One such goal could, for example, be the establishment of an AI ecosystem. To derive input and output indicators from that goal, one must clearly define what an AI ecosystem really is, what its distinguishing dimensions are, and how one might foster them and measure their development.

	Input Indicators	Output Indicators
Quantitative	Amount of funding	Number of AI Patents
Qualitative	Agile research funding	AI Quality Standards

Table 1: Indicator matrix with examples, source: Stiftung Neue Verantwortung

In the context of an AI strategy, input indicators are therefore all policy measures to strengthen the AI ecosystem. One can then differentiate between quantitative and qualitative input indicators. Quantitative, and therefore easily observable, input indicators include, for example, the budget that should be allocated to research funding or new investment funds. A qualitative input indicator would be a political measure, for example new regulations for the allocation of research funding that reduce expense and bureaucracy and boost competition. Output indicators relate to the achievement of goals. The core issue is whether the measures will lead to the result that has been established as the goal. However, output indicators do not have to correlate with input indicators. One can also use them to assess different dimensions of an AI ecosystem – even those not directly addressed by policy, such as the numbers of startups that are founded. One can again distinguish here between quantitative and qualitative dimensions.

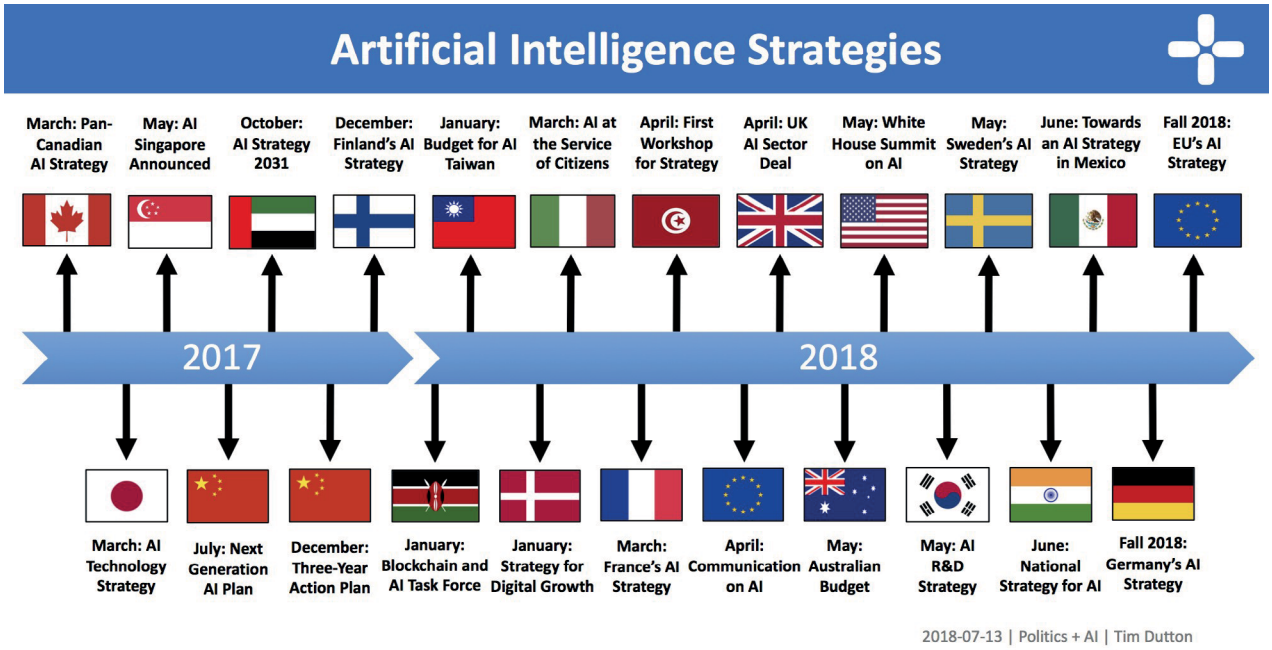
With this paper, we would like to stimulate a discussion about input and output indicators related to national AI strategies. To generate ideas for

the development of such indicators, we examined whether and how already-published AI strategies define their goals and measures to validate the achievement of those goals. The national AI strategies provide some good approaches and ideas, but lack an in-depth and systematic engagement with indicators and benchmarks. In a further chapter, we examine the methodologies of existing AI indices. In both cases, we were concerned with working through core questions and providing an initial overview. We would like to caution the reader that this is not a comprehensive study. But we hope to stimulate further discussion and research with this paper.

The majority of indices and reports we examined suffer from significant methodological weaknesses. The reports have generally been received uncritically by the media and the public. Therefore, we also want to spark a critical debate around AI reports and benchmarks. That said, we do not wish to generally call into question the importance and utility of these reports. So, in the third chapter, we set out our own ideas for the development of an empirical foundation for an AI strategy. Our approach hinges on a dynamic interaction with AI trend monitoring, as a means to providing the basis for the continuing engagement with and further development of indicators. With this paper, we hope to contribute to the discussion about how to define goals for national AI strategies and about how to measure them.

Success indicators in national AI strategies

Political decision-makers around the world regard AI as a key technology. As shown in the graph below, many countries have begun processes to assess the potentials and risks of this technology and the larger strategic implications. The resultant AI strategy papers serve as an initial empirical basis for tackling the question of how progress and performance indicators for a national AI strategy may be developed and defined. For this short discussion paper, we could not provide a systemic analysis of all the strategies that have been published. Rather, we selected a few prominent examples for examination, regarding the extent to which they define clear goals and delivery indicators. The already-introduced distinctions between input and output and quantitative and qualitative have provided an analytical framework for this purpose.



Graphic 1: Source https://medium.com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd

China – Planned Economy 4.0?

The Chinese government introduced its "New Generation Artificial Intelligence Development Plan" in July 2017.[2] This attracted a great deal of international attention, due to the global ambitions expressed in the plan, as China is already strategically well-positioned regarding AI development. One of the main drivers is the size of the Chinese market, which boasts the world's largest number of internet users and consequently enormous troves of data for AI development. Chinese online and technology firms have also undergone rapid development. China is now turning its ambitions into official government goals. It wishes to become the world's preeminent AI nation by 2030. The strategy builds on existing initiatives for the promotion of internet-connected technologies and smart manufacturing.[3] In its AI strategy, the Chinese government places great emphasis on data-hungry machine-learning approaches. Current shortfalls in basic research should be offset through investment in research funding. In addition to boosting AI research

2 The analysis relies on a translation of the original document as available here: New America (2017). A Next Generation Artificial Intelligence Development Plan, https://www.newamerica.org/documents/1959/translation-fulltext-8.1.17.pdf

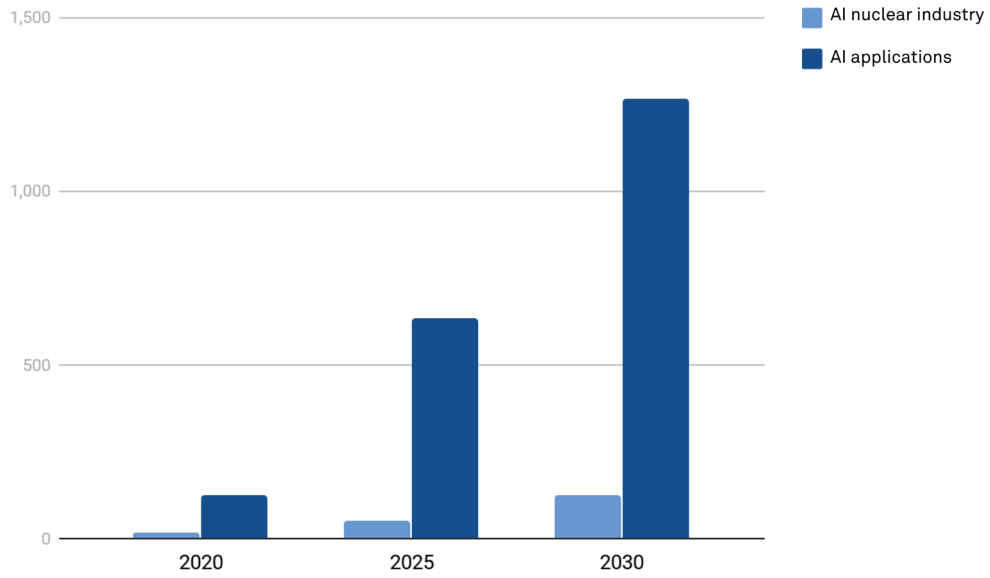
3 See, for example, the strategy published by the State Council of the People's Republic of China in 2015: Made in China 2025 – 中国制造, http://www.cittadellascienza.it/cina/wp-content/uploads/2017/02/IoT-ONE-Made-in-China-2025.pdf.

and application, the aim is also to achieve international influence through the development and implementation of global AI standards.[4]

2020	Technical know-how and applications are the same level as leading nations internationally
	AI companies are an important growth driver
2025	China makes breakthroughs in AI research and will be the world leader in certain technologies
	AI will be the lead driver in economic and social development
2030	Chinese research is dominant and China will be the best center for AI innovation globally

Table 2: Overview on benchmarks of the chinese AI strategy, source: Chinese strategy, p. 5ff.

The document lacks a definition of AI, but it does reflect a deep engagement with fields of application and research trends. Along with data-driven approaches, it also mentions theoretical and methodological approaches derived from neuro-science. In the tradition of grand industrial policy measures, China's AI strategy takes a classic top-down approach. In line with previous five-year plans, milestones are defined for the years 2020, 2025 and 2030.



Graphic 2: Aspired worth of chinese AI companies in billion euros. Source: chinese strategy, p.5ff.

4 See https://www.newamerica.org/cybersecurity-initiative/digichina/blog/chinese-interests-take-big-seat-ai-governance-table/

The targets include quantitative output indicators that are summarised in the above graph. The AI industry is expected to increase its economic contribution to GDP to around €1.3 trillion by the year 2030. For context, total Chinese GDP was around €11 trillion last year.[5] Although the Chinese government is already investing great sums in AI development, the AI strategy contains no quantitative input indicators, such as information about planned state expenditure on research funding. Instead, the strategy lists measures that are supposed to be implemented over the next few years. For example, open platforms should promote the development of AI applications and the collaboration between research, development and industry.[6] The strategy also refers to existing plans to train up thousands of new AI experts annually.[7] The strategy has been further specified by a three-year plan that sets out, for example, accuracy targets for medical AI systems, including reductions in diagnostic errors.[8]

U.S. – Between Silicon Valley and the Pentagon

In the U.S., the AI debate was initiated under President Obama, resulting in several internationally acclaimed reports. In addition to a national AI research and development plan in October 2016[9], a report was published two months later on the economic impact of automation.[10] However, the issue has been deprioritized under President Trump. In May 2018, the White House invited leading experts for an exchange that resulted in a brief overview paper about existing initiatives and measures.[11] One cannot, however, avoid the impression that the U.S. government is largely leaving the initiative to Sili-

5 National Bureau of Statistics of China (2018). Homepage, http://data.stats.gov.cn/

6 New America (2018). Translation: Chinese government outlines AI ambitions through 2020, https://www.newamerica.org/cybersecurity-initiative/digichina/blog/translation-chinese-government-outlines-ai-ambitions-through-2020/

7 http://www.1000plan.org/en/plan.html

8 The Chinese AI strategy is also distinguished by its strong security dimension. AI technology development in the private sector or at state universities and research centres is to be transferred to the military. https://www.cnas.org/publications/commentary/tsinghuas-approach-to-military-civil-fusion-in-artificial-intelligence

9 Networking and Information Technology Research and Development (2016). The National Artificial Intelligence Research And Development Strategic Plan, https://www.nitrd.gov/PUBS/national_ai_rd_strategic_plan.pdf

10 Executive Office of the President (2016). Artificial Intelligence, Automation, and the Economy, https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/Artificial-Intelligence-Automation-Economy.PDF

11 The White House (2018). Summary of the 2018 White House Summit on Artificial Intelligence for American Industry,https://www.whitehouse.gov/wp-content/uploads/2018/05/Summary-Report-of-White-House-AI-Summit.pdf

con Valley and the Department of Defense regarding military applications.[12] This includes the creation of agencies that selectively invest in companies that have developed militarily relevant AI technology. The Pentagon and the CIA have, with Defense Innovation Unit Experimental (DIUx)[13] and In-Q-Tel[14] respectively, financially potent vehicles with which to pursue this goal. However, military cooperation by tech companies is highly controversial, as the internal and external criticisms over Google's cooperation with the Defense Department in "Project Maven" – and its resultant withdrawal of that cooperation – underscore.[15]

In the light of the examples of China and many other countries, calls for the development of a national AI strategy have become louder in the U.S.[16] So far, there is only the national AI research plan.[17] However, this plan is broadly conceptualised and also addresses overarching social, economic and security-related issues – in line with what one would expect from a national AI strategy. The research plan contains a chapter on the importance of benchmarks and standards in strategically steering AI development. However, these benchmarks and standards relate exclusively to the evaluation of AI applications' functionality and performance. Benchmarks relating to the successful implementation of the research plan are not mentioned.

The U.K. – Europe's AI Pioneer

The British government laid out its AI ambitions in April 2018, in a so-called AI Sector Deal.[18] The House of Lords concurrently worked on an AI report, to which the government has provided a separate response.[19] This abundance of activity testifies to the importance of the topic for the British government.

12 https://www.golem.de/news/usa-pentagon-fordert-ki-strategie-fuers-militaer-1808-136216.html

13 https://www.diux.mil/

14 https://www.iqt.org/

15 https://gizmodo.com/google-is-helping-the-pentagon-build-ai-for-drones-1823464533

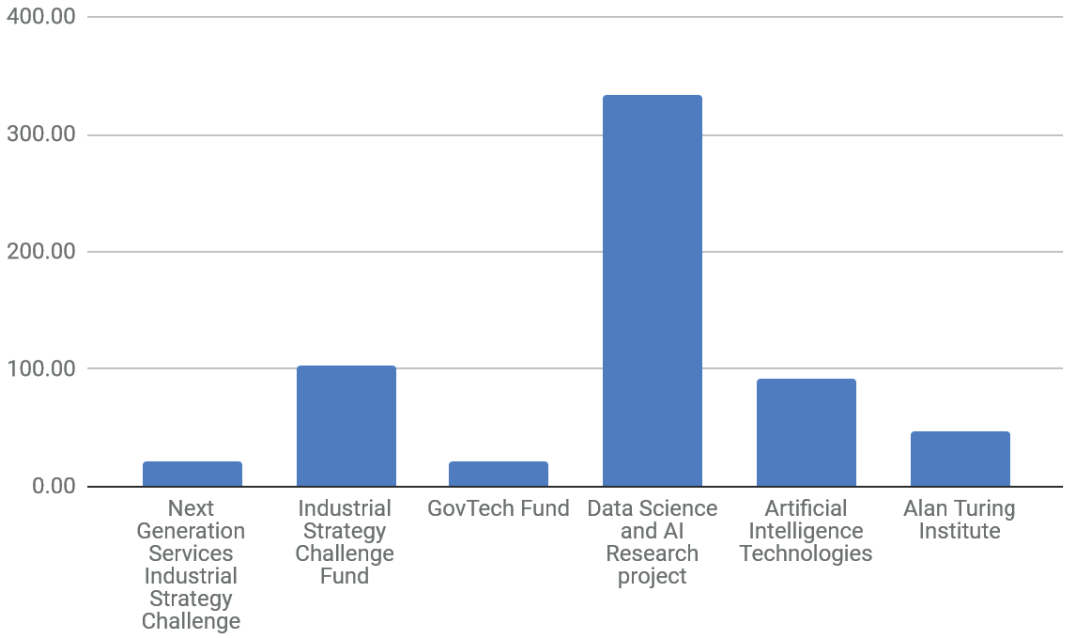
16 Delaney, J. (2018). France, China, and the EU All Have an AI Strategy. Shouldn't the US?, Wired, https://www.wired.com/story/the-us-needs-an-ai-strategy/

17 National Science and Technology Council (2016). The National Artificial Intelligence Research and Development Strategic Plan. https://www.nitrd.gov/PUBS/national_ai_rd_strategic_plan.pdf

18 Department for Business, Energy & Industrial Strategy and Department for Digital, Culture, Media & Sport (2018). Artificial Intelligence Sector Deal, https://www.gov.uk/government/publications/artificial-intelligence-sector-deal

19 House of Lords (2018). AI in the UK: ready, willing and able?, https://publications.parliament.uk/pa/ld201719/ldselect/ldai/100/10002.htm

We focus on the AI Sector Deal, as it contains some definitions of indicators and benchmarks. The AI Sector Deal lacks a definition of AI, but makes clear that AI is a key technology for data processing. There is also great emphasis on deep learning, a machine-learning approach that is currently receiving particular attention. The AI Sector Deal is focusing on how to boost business opportunities and economic competitiveness through AI. It primarily contains input indicators, in particular those regarding the allocation of funds to implement its proposed policies.



Graph 3: Planned British investments in different fields in million Euros. Source: AI Sector Deal p. 13.

The British plan also includes further policy measures in five key strategic areas: ideas, people, infrastructures, business environment and places. This is where some output indicators are mentioned. For example, the number of government-funded doctoral students in the field of AI is supposed to rise to 2,000 by 2025. More than 2,000 AI experts are to be brought into the country through a special visa programme. In order to provide the data transfer capabilities that are needed for AI applications, 95% of all households should be given access to "superfast" broadband. There is also a goal of mobilising over €7.8 billion in additional venture capital for AI startups over the next decade. In order to implement the strategy, the government intends to establish a new Office for Artificial Intelligence. This office is supposed to develop and monitor success criteria in the aforementioned strategic areas.

France – Using AI to Return to Former Strength

President Macron unveiled the French AI strategy at the "AI for Humanity"- conference in March 2018.[20] The strategy was developed under the stewardship of the noted mathematician and parliamentarian Cédric Villani, and attracted widespread publicity, largely due to its strong political backing.[21] The more-than-140-page "Villani report" lays out France's vision for the development and use of AI, and identifies the most important social, industrial and political hurdles in France's path to becoming one of the world's leading locations for AI. The French strategy also avoids defining AI, referring instead to the historically multifaceted development of AI as a research field that was shaped by contributions from mathematics, cognitive science, computer science and other related disciplines. Along with scientific achievements such as the latest developments in so-called deep learning, the report cites Chinese and American efforts, and massive investments by U.S. technology firms, as evidence of AI's strategic importance.

The Villani report deals extensively with the various dimensions of AI regarding society, industry and ethics, while identifying many important policy areas. However, apart from a few exceptions, it lacks concrete input and output indicators that are linked to the strategy. The report does not include any firm investment proposals. When presenting the report, President Macron said the French government would set aside €1.5 billion over the next four years for AI research.[22] The strategy's input indicators are very vague policy measures, such as promoting data pools, boosting the visibility of French AI firms, and using public procurement programmes to promote AI-based products. Other measures, such as the establishment of a network of French AI research institutes, are discussed in greater detail. Concrete output indicators are not mentioned at all in this strategy.

Finland – Intelligently Identify and Seize Opportunities

The Finnish government commissioned a working group to establish an AI strategy. This process is still underway, though the working group presented

20 Gouvernment (2018). Artificial Intelligence - Making France a Leader, https://www.gouvernement.fr/en/artificial-intelligence-making-france-a-leader

21 Villani, C. (2018). For A Meaningful Artificial Intelligence - Towards A French and European Strategy, https://www.aiforhumanity.fr/pdfs/MissionVillani_Report_ENG-VF.pdf

22 Vinocur, N. (2018). Macron's €1.5 billion plan to drag France into the age of artificial intelligence, Politico, https://www.politico.eu/article/macron-aims-to-drag-france-into-the-age-of-artificial-intelligence/

its first report in December 2017.[23] In that report, the experts engage – albeit briefly – with the problem of defining AI, and orient their own understanding strongly toward the transfer of human intelligence to machines. The strategy stands out among its peers in its clear analysis of the development, dynamics and potentials of AI. It is furthermore striking that the report deals not only with potential and existing strengths, but also clearly identifies Finland's weaknesses. As a relatively small country, the domestic resources for AI research and the internal market for AI applications are inevitably limited, and the authors do not harbour the illusion of Finland becoming one of the world's leading AI locations. Instead, they make an effort to identify the niches in which Finland might play an important role. They also openly acknowledge and discuss problems with the commercialisation of research.

The report identifies eight strategic areas of action. The most important actors are listed for each area, along with implementation possibilities, illustrated with practical examples. This sets the report apart from the generally abstract action recommendations of other countries' strategies. However, the report contains almost no quantitative input indicators and no output indicators at all, apart from the overarching goal of spending 4% of GDP on innovative development in the long term. Apart from adding €100 million to the budget for promoting innovation, the report's only input indicators are recommendations for action.[24] At the end of the report, there is however a reference to the need to develop indicators, to enable the measurement of progress in implementing individual actions. This insight is just one of many factors that make this report stands out positively among the national AI strategies we examined.

European Union – Between Ethics and Investments

The European Commission also sees AI as a key technology worthy of special attention. In the light of competition with China and the U.S., efforts need to be coordinated and aligned at the EU level. To stimulate this process, the Commission published a communication on AI in April 2018.[25] In it, the Commission committed to greater coordination of member states' national initiatives through a pan-European framework, along with the embedding of

23 Ministry of Economic Affairs and Employment (2017). Finland's Age of Artificial Intelligence, Publications of the Ministry of Economic Affairs and Employment 47/2017, https://julkaisut.valtioneuvosto.fi/bitstream/handle/10024/160391/TEMrap_47_2017_verkkojulkaisu.pdf?sequence=1&isAllowed=y

24 Ministry of Economic Affairs and Employment (2017) p. 53

25 European Commission (2018). Communication Artificial Intelligence for Europe, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe

efforts in ongoing projects such as the digital single market. The Commission is working with a very broad definition of AI that can take in the most important approaches to AI development.

The EU paper focuses on two key priorities. Firstly, investments in AI technologies, in both research and industry, should be greatly expanded in order to strengthen the EU's position in the competitive landscape, most importantly in relation to China and the U.S. Particular emphasis is placed here on cooperation between research and industry. On the other hand, the social and ethical issues associated with the technology also receive a great deal of attention, and should be dealt with in greater depth in the coming years. The EU document contains only input indicators. The paper does not present a comprehensive AI strategy, but serves rather as a stimulus to advance the debate at the EU level and to highlight the first concrete measures. The most important quantitative input indicators refer to various funding programmes through which the Commission hopes to advance AI research in the EU. Public and private investment in AI is supposed to increase from €4-5 billion to a total of €20 billion. However, in order to manage the achievement of this and other ambitions, there is a need for corresponding indices. Even though the EU has much experience with cross-border benchmarks and indices, nothing concrete is (yet) to be found in the EU paper.[26]

The national AI strategies lack concrete goals and indicators

The examined AI strategies contain many input indicators, consisting mainly of relatively vague policy measures and initiatives. Quantitative input indicators are more concrete and therefore more easily measured. These mostly consist of the sums of public money that are allocated to the implementation of specific measures, such as the expansion of AI research. Such clearly measurable input indicators are much less common in the strategies than general policy measures. Only very few strategies include as output indicators concrete benchmarks (outputs) that should be achieved through the strategy.

There are several reasons for this. In most of the strategies, AI is defined very broadly, if at all. This breadth indicates openness to the many different research and development approaches that currently fall under the buzzword of

26 For example, the European Commission's Digital Economy and Society Index. https://ec.europa.eu/digital-single-market/en/desi

"AI". However, the lack of a clear definition of AI also makes it impossible to define measurable output indicators – if it is not clear what falls under the scope of AI, one cannot ascertain how many more AI researchers or startups there should be in the future.

Another reason for the lack of output indicators is that national AI strategies should be understood primarily as communications tools. In that sense, the path is itself the goal. The development of a national AI strategy promotes strategic engagement with this key technology within government. The focus here is on fundamental issues. It is about the potential of new technologies, the opportunities and risks for industry and society, and positioning in the international competitive landscape. It is not only the relevant ministries that are involved here. In some countries, the strategic process is also used to stimulate wider public discussions. In this context, questions of definitions and indicators seem too detailed and specialised.

Table 3 provides an overview of the quantitative input and output indicators that we identified in the national AI strategies.[27] They contain many more input indicators than output indicators. The input indicators are not generally backed by resources, instead comprising vaguely formulated policy measures. There are also no easily measurable benchmarks against which implementation progress and strategic success can be gauged. Only China and the U.K. define quantitative output targets. The Finnish strategy at least promises the development of such indicators.

Subject Area	Input Indicators	Output Indicators
Research	- Research spending (CHN, EU, FIN, FRA, UK, USA) - Planned new research centers (CHN, EU, FIN, FRA, UK, USA) - Increase general attractiveness of research locations (CHN, EU, FIN, FRA, UK, USA)	- Internationally recognized contributions to basic AI research (CHN) - Number of doctoral students (UK) - Number of Visas for researchers (UK)

27 The table's evaluations are based on text analyses of the respective countries' strategies. Indicators in these documents are not ordinarily listed separately but rather in the running text, which makes clear identification difficult. Moreover, inclusion in the table is merited by the mention of a particular measure, e.g. research expenditure, without the need for a reference to a particular amount, e.g. €X until 2030.

Subject Area	Input Indicators	Output Indicators
Economy	- State funding of the AI economy (CHN, EU, FIN, FRA, UK, USA) - State AI Procurement (CHN, FRA, UK, USA) - State funding of IT infrastructure (CHN, EU, UK) - Eliminate regulatory hurdles / incentivize AI use through companies (EU, FIN, USA) - Expansion of Open Data Initatives (EU, FIN, FRA)	- Increases in productivity and competitiveness of the economy through AI (UK, FIN) - Benchmarks for added AI value (CHN)
Education/ Expertise	- Invest in STEM in schools / universities / vocational education / continuing education (EU, FIN, FRA, UK, USA) - Introduce new courses with AI focus (EU, FIN, FRA, UK, USA)	- Leading international role in AI Ethics / Data use (EU, FRA, UK) - Define international AI technical standards (CHN, USA) - Be a trendsetter for EU debate (FIN)

Table 3: Quantitative Input and Output Indicators in the main AI activities according to national AI strategies, Source: Stiftung Neue Verantwortung

If the strategies are to become more than declarations of intent and communications tools, goals and the resources for achieving them need to be more clearly defined. Thus one cannot avoid an analysis of definitions and indicators. This challenge is already taken into account in some national strategies – of those discussed here, China and the U.K. stand out in particular. However, none of the strategies discussed here contains a comprehensive approach for the development of input and output indicators.

AI Indices

Many reports and analyses about AI capabilities and advances have been published in recent years. Some of the analyses are based on empirical inquiries with the aim of systematically engaging with strengths and developments in AI research, investments and applications. We consider here a selection of these AI indices in terms of their methodology. In doing so, we exclusively considered indices that are focused on AI. Our goal was not to engage with and systematically analyse all AI indices, as this would have gone far beyond the scope of this short paper. Rather, our aim was to tease out, through examination of these indices' methodology, some initial sugge-

stions, ideas and challenges for the development of benchmarks that may be applied to an index for the German AI strategy.

We identified a wide spectrum of AI indices, the approach and scope of which vary widely. However, we could distinguish the approaches according to four core methodologies.

Methodology	Advantage	Disadvantage
Survey: Mostly expert surveys and interviews	Deeper insights that usually can not be drawn from publicly available data	The expert selection and response rate shape the results (bias), subjective impressions from experts
Composition: Evaluation and weighting of serveral indices	Relatively simple to implement because no new data sources necessary	Unsuited for looking at new developments, the selection of indices shape the results (bias)
Data driven: Gathering and analysis from easily accessible data sources	objectivity based on statistical methods	The availability of certain data sources shapes the results (bias)
Indicator driven: Indicators are derived from theoretical analysis and understanding	Results based on a deeper understanding of the object of investigation from which indicators are derived	Often there is a lack of data sources necessary for implementation or implementation is extremely expensive because new data sources and analytics must be specially developed

Table 4: Overview of the index methodologies. Source: Stiftung Neue Verantwortung

Each methodological approach comes with strengths and weaknesses. When surveying experts and decision-makers, one can address more complex topics and go more into depth. Particularly useful are questions for which there are no good quantitative data sources or statistical surveys to provide answers. Therefore, surveys are well-suited for identifying and exploring new trends. However, the outcome of the survey depends very much on the choice of expert groups, their response rates and quality, and the choice and framing of the questions. The responses generally also contain unverifiable information and subjective assessments. For example, answers about whether companies invest enough in AI development can vary widely, depending on whom in a company one asks, how well-informed the respondents are, how they evaluate the situation, and what information those people have and wish to disclose.

We referred to the approach of developing a new index from existing indices as “composition”. This approach is relatively easily implemented, as it does

not require the development of new data sources, nor does it demand new data collection. However, unlike with surveys, new trends cannot be detected nor investigated. The quality of the composition is also heavily dependent on the quality of the indices that are used, along with the question of whether these can be usefully aggregated into a new overview.

Data-driven approaches define indicators according to the availability of data. Digitalisation and new data collection and analysis techniques, such as the automated capture and analysis of website text (using so-called web crawlers), provide new sources of data for analysis. However, there is a stronger tendency here to align indicators with available data sources, rather than by evaluating which indicators are most suitable for addressing particular problems. Datasets, even when easily obtained and analysed with complex statistical methods, do not provide good answers if they do not adequately reflect the underlying issue.

Instead of making the development of indicators dependent on data availability, indicator-driven approaches take the development of indicators as their starting point. Such approaches derive the index's indicators from a deep theoretical understanding of the phenomenon in question. At first glance, this appears to be the ideal approach to index development. However, even the best indicators, that have been derived through a deep theoretical understanding of the research object, are of little use without a suitable measuring technique or access to the required data. The perfect indicator that cannot be operationalised only has theoretical value but is of little practical use.

The examination of these different methodological approaches shows there is no one perfect approach. Each has its own strengths and weaknesses, and it is often the case that not only one is chosen, but rather a combination. Elements of all four are therefore found in varying degrees across the indices under examination. In reality the classification is usually not as clear cut as portrayed in the table below. Some indices combine multiple approaches. For example, the study *AI: The New Frontier*, from McKinsey Global Institutes, is based on both a survey and a data-driven analysis of investments in AI. And even though the considerations regarding the use of individual indicators often remain opaque, it should nonetheless be assumed that the authors of all the indices considered this question when developing their index or ranking.

Our classification is therefore simply based on an assessment of which methodological approach prevails in an index. None of the indices can be regarded as purely indicator-driven, because they simply lack the necessary

in-depth analysis of their research object (most notable in the lack of discussion of how to define AI). However, the selection of indicators is always predicated on a theoretical assumption about the research object and its relation to the indicator. This problem is discussed in greater detail below.

Publication/ Platform	Editor	First Publication	Current Publication	Aim	Coverage	Methodology
AI Maturity	Infosys	2016	2016	Overview of AI maturity in various industries	7 Countries	Survey
AI: The Next Frontier	McKinsey Global Institute	2017	2017	Shows AI developments and possible economic applications	10 Countries	Survey
AIQ	Accenture	2017	2017	Shows the distribution and readiness of AI in private companies	10 Countries	Survey
Automation Readiness Index	Economist Intelligence Unit & ABB	2018	2018	Measures the ability for different countries to adapt their economies to automation	25 Countries	Composition
Government AI Readiness Index	Oxford Insights	2017	2017	Shows how ready government services are for benefitting from AI	35 Countries (OECD)	Composition
AI Index	AI 100	2017	2017	Overview of different AI dimensions (Research, application, investment, etc.)	Global	Data driven
AI Progress Measurement	Electronic Frontier Foundation	2017	2017	Compilation of various problems / benchmarks to measure the advancement of AI research	Global	Data driven
The European Artificial Intelligence Landscape	Asgard & Roland Berger	2017	2017	Overview of AI Startups	Europa	Data driven
Global AI Talent Report	Jean-François Gagné	2018	2018	Overview of Global AI talent pool	Global	Data driven
AI Trends	CB Insights	2018	2018	Shows trends for industrial AI application	Global	Präsentation von Trends
State of AI	Nathan Benaich & Ian Hogarth	2018	2018	Overview of developments in the areas of AI research, talent, industry and policy	Global	Präsentation

Looking at these indices, it is noteworthy that most were created by consultants or consultancy firms. It is therefore hardly surprising that the analyses of AI trends and advances in almost all the reports are accompanied by recommendations and strategic advice. The consultancies use the reports to position themselves in new issue areas. Most of the indices do not stand up to scientific scrutiny and their authors do not claim that they do. Above all, there is a lack of transparency regarding the methodology and consequently its flaws and limitations. Rather than openly discussing the limitations of their indicators and critically classifying the findings of the index, the methodology is sparsely described, with information on it often being hidden in footnotes or in a concluding appendix.

The fundamental problem with all the examined indices is the fact that they all fail to sufficiently engage with the subject at hand. Most reports only contain a very broad definition of AI that focuses primarily on the comparison to human intelligence. For example, *Accenture* characterises AI technologies as those that "extend human capabilities by sensing, comprehending, acting and learning".[28] *McKinsey* sees in AI the "ability of machines to exhibit human-like intelligence".[29] However, neither goes on to explain how, under this broad definition of the term, specific technologies should or should not be classified as AI.

Such a deduction should nonetheless be made when, for example, dealing with AI investments. This requires a clear definition of which investment counts as an AI investment and which does not. This may indicate another reason for the popularity of the survey methodology: it allows data to be collected without clear definitions. Answers from executives about how or how strongly their companies engage with the field of AI are therefore dependant on the respondents' understanding of AI. If respondents are not given clear and meaningful definitions and boundaries for AI, this raises major questions about the comparability of their individual answers.[30] It suggests that they are expressing nothing more than a rather diffuse, impressionistic pic-

28 Accenture (2017). Boost your AIQ - Transforming into an AI Business, https://www.accenture.com/t20170614T050454Z__w__/us-en/_acnmedia/Accenture/next-gen-5/event-g20-yea-summit/pdfs/Accenture-Boost-Your-AIQ.pdf#zoom=50, p. 5

29 McKinsey Global Institute (2017). Artificial Intelligence - The Next Frontier?, https://www.mckinsey.com/~/media/McKinsey/Industries/Advanced%20Electronics/Our%20Insights/How%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/MGI-Artificial-Intelligence-Discussion-paper.ashx, p. 6

30 It cannot be ascertained whether, and if so in what form, this was done in the context of the survey, as the reports describe their survey methodology only in general terms, without disclosing details.

ture – hardly something that can be used as solid foundation for classifying companies according to their activities or for the creation of rankings.

Although Accenture's report did not address in any depth the question of which technologies ultimately fall under AI, the consultancy did have to engage with the question. Alongside interviews, the Web was also searched for relevant business activities in the field. A list of AI technologies and applications was created for this purpose, as documented at the end of the report.[31] To operationalise its broad definition of AI, McKinsey explained that it focused on five types of AI system: robotics and autonomous vehicles, computer vision, language, virtual agents and machine learning. As for why these particular categories were chosen and how they should be understood, there is no further discussion. There is also no indication that these technologies have different potential uses in the various economic sectors that are compared in the report, nor that this fact probably explains much of the variance in the degree to which these sectors use the technology.[32]

Data-driven approaches have an advantage over surveys, in that they are able to avoid the methodological weaknesses associated with interpersonal communication. Quantitative inquiries and analyses are frequently associated with objectivity and higher validity. However, even data-driven approaches are not without problems and potential distortions. A classic example of a data-driven approach is the collection and evaluation of the geographical distribution of AI startups by *Asgard* and *Roland Berger*. The original database comprised a sizeable Excel table of AI startups from Asgard. As this database already existed at Asgard, it made sense for both businesses to focus on AI startups. However, this data-driven approach is based on strong assumptions that are not further discussed. Comparing the strength of AI ecosystems on the basis of numbers of startups implies that AI startups are crucial for the strength and potential of AI ecosystems. University research and corporate applied research and development are not documented – probably because the additional data collection and analysis would have been too burdensome and costly. The authors even themselves concede that the dynamic progress in AI development and application is not only driven by startups, but also by large digital platforms and research institutes.

On a positive note, *Asgard* makes its dataset publicly available. However, this does not resolve the methodological issues. There is no explanation as to

31 Accenture (2017), p. 28

32 A good overview of different application possibilities is offered by the Expertenkommission Forschung und Innovation in its introductory overview of autonomous systems, p. 65-81 https://www.e-fi.de/fileadmin/Gutachten_2018/EFI_Gutachten_2018.pdf

how the data was obtained and how confident we can be about its accuracy. Also it is not clear what *Asgard* regards as an AI technology and what not. Alongside machine learning, deep learning, image recognition and speech processing, other "frontier AI technology" is taken into account without any specification of what that means. And how was coherence and quality in the data collection assured? Were specific sources used, or is the list mainly based on desktop research? How did the authors overcome the language barrier mentioned in the report, for example in their coverage of Chinese AI startups? In addition, the term "startup" is not defined, with the result that the dataset treats large, highly valued AI startups with deep technical expertise as equivalent to small "garage startups". For example, the list includes the firm DeepMind, which has existed since 2010, was bought by Google for around €580 million[33] and has around 50 developers, alongside the Berlin startup Bunch, which was founded in 2016, has fewer than 10 employees and lives off seed funding. This raises the question of how meaningful a comparison based on numbers of startups really is, when one ecosystem may have only a few startups that are nonetheless highly valued and international active, while another may have many startups that are undercapitalised and only locally active. Without specifying selection criteria and taking into consideration factors such as employee numbers, the degree of internationalisation and market capitalisation, there is a serious danger of comparing apples with oranges.

The Global AI Talent Report is also data-driven.[34] The editor, Jean-François Gagné, uses data from the professional network LinkedIn for a global analysis of the geographical distribution of AI experts. The programmes of leading AI conferences are also utilized. The report openly discusses the restrictions of these data sources on the validity of the analysis and the pitfalls for drawing conclusions from it. The analysis begins with an examination of the question of how AI talent should be defined. In doing so, the Global AI Talent Report relies on a mix of relevant domain knowledge in AI sub-disciplines, programming knowledge and scientific training (at the PhD level). It attempts to grapple with the problem that LinkedIn users self-report their competencies and may evaluate their skills incorrectly or too highly. Also addressed is the issue that LinkedIn's prevalence varies strongly across different regions of the world. Even with these limitations, interesting developments and trends can be gleaned from the data. The Global AI Talent Report is a good example of

33 Economist (2016). What DeepMind brings to Alphabet, https://www.economist.com/business/2016/12/15/what-deepmind-brings-to-alphabet

34 Gagne, J. (2018). Global AI Talent Pool Report, http://www.jfgagne.ai/talent/

the potential of new data sources, such as data generated by professional networks, for the development of indices.

The AI Index, which is maintained by the scientists Yoav Shoham (Stanford University) and Eric Brynjolfsson (MIT), is based on a wide variety of different indicators. The many analyses featured in the index are essentially data-driven. Based on the evaluation of freely accessible web-based data sources, they range from general developments in AI to specialised evaluations of science, economics, open source software, public awareness and indicators of AI applications' technical performance. The report is notable for its thematic broadness and the wide range of its indicators and benchmarks. However, the authors warn from the outset against drawing premature conclusions, in particular regarding country comparisons and international trends, due to the fact that the data sources are largely from the U.S. and other countries are often covered inadequately, if at all.[35] The authors therefore characterize their report as a long-term, collaborative project. They explicitly request suggestions, criticisms and references to further data sources. All datasets are published on the report's website, and each data source is discussed in the appendix with regard to definitions and validity. As one of the few university-based projects, the AI Index stands out for its transparency and critical approach to methodology. Given its broad ambitions, the report also provides many interesting reference points for the development of AI benchmarking or indices in the context of national AI strategies .

The Electronic Frontier Foundation's (EFF) AI Progress Measurement tracks important progress in AI development.[36] The EFF's project documents performance improvements in key AI fields such as image or speech recognition. Within many AI problems, there is an emphasis on the reduction of failure rates, as shown in the tracking of image or speech recognition progress in recent years. But AI Progress Measurement also tracks AI system advances in the mastering or complex strategy games.[37] The index provides a valuable overview of technical progress in key problem areas within AI research. Additional projects and approaches that deal with technical benchmarks for AI software and hardware are listed in Table 6.

35 AI Index (2017), 2017 Annual Report, https://cdn.aiindex.org/2017-report.pdf, p. 8

36 Electronic Frontier Foundation (2018). AI Progress Measurement, https://www.eff.org/de/ai/metrics

37 Open AI Five is one of the prominent examples where progress in AI development id documented and measured according to success in strategy games https://blog.openai.com/openai-five/

Kaggle Competition	https://www.kaggle.com/competitions
Stanford DAWNbench	https://dawn.cs.stanford.edu/benchmark/
TensorFlow Benchmarks	https://www.tensorflow.org/performance/benchmarks
MLPerf Benchmark	https://mlperf.org/
ImageNet Large Scale Visual Recognition Challenge	https://www.image-net.org/challenges/LSVRC
Discussion Benchmarks	https://siliconangle.com/2018/05/07/challenge-finding-reliable-ai-performance-benchmarks/

Table 6: Technical Benchmarks and Competitions. Source: Stiftung Neue Verantwortung

There are also two indices in our list whose analyses rely on existing indices. As previously mentioned, we refer to this type of index as "composition". The advantage of this approach is that, because no new data sources need to be cultivated, it is relatively easy to implement. The disadvantage is the reproduction of the shortcomings and flaws of the indices that are used, and that questions which go beyond the scope of the indices cannot be addressed with this method. The Government AI Readiness Index, from the consultancy Oxford Insights, consists of a score that assesses the ability of all OECD countries' governments to benefit from the use of AI systems in their own work and in the public sector more broadly.[38] The index does not need to engage deeply with the definition of AI, because it is not essentially about AI. Instead, the index relies on unelaborated, though certainly not implausible, assumptions that countries with better digital infrastructure and more innovative public sectors are more likely than others to integrate AI applications into their work. Although the indices used to calculate the final score are mentioned, there is no explanation of how exactly these indices are combined and weighted. Given the surprising outcomes further explanations would be helpful. For example, Estonia, the world leader in e-government, ranks only as number 23 – behind Mexico and Poland.

The Economist Intelligence Unit's (EIU) Automation Readiness Index ranks countries according to their capacity and readiness of their governments to deal with the anticipated AI-associated transformation of economies and societies. The analysis focuses on three areas: innovative strength, education policy and employment policy. The Automation Readiness Index ranks 25 countries in each of these areas, from which it derives a final score. In contrast with the Government AI Readiness Index, the Automation Readiness Index states not only which indicators have been used, but also how they

38 Oxford Insights (2017). Government AI Readiness Index, https://www.oxfordinsights.com/government-ai-readiness-index/

have been weighted. The total score is based on 52 indicators, of which 45 were developed by the EIU itself. Seven additional indicators from other organisations are used. However, the report does not contain much information about its own 45 indicators on which the final score is based. Most of the indicators relate only to the existence of certain government programmes, such as those for research funding or education. There is no consideration of the resources that are devoted to these programmes, or the question of their effectiveness. The index therefore provides only a rough overview of whether countries are engaging with issues around AI and automation in various policy fields. However, contrary to what is suggested, it cannot be deduced from the collected data how well-prepared these countries really are.

Another frequently encountered format is the AI trend report. While these reports admittedly do not neatly align with our index methodology, they do provide valuable insights, particularly regarding new developments. Therefore, they should not go unmentioned here. CBInsights' "Top AI Trends to Watch in 2018" report identifies 13 trends in the field of AI.[39] These trends could be harbingers of larger developments. One trend involves, for example, the question of how the reduction in labour costs through automation might lead to a revival of industrial production in the U.S. Other trends deal with new use cases for AI or comparisons between the numbers of patent applications in the U.S. and China. New research trends, such as the architectures of neural networks or edge computing, are also covered. Nathan Benaich and Ian Hogarth's "State of AI" presentation provides an even more comprehensive overview of the latest AI trends. It is divided into several chapters: significant research advances in hardware and software, human capital (AI talent), industry and applications, society and politics and their own forecasts for further development. The presentation includes 156 slides and closes with the personal predictions of both authors. Trend reports fall a little outside of our scope, as they use no systematic methodology, being instead heavily influenced by their authors' expertise and judgement. However, the reports provide a valuable resource for anyone monitoring trends in the field of AI.

Cost vs Validity: the dilemma of AI indices

A brief analysis of some of the best-known AI indices provides many interesting starting points that can aid the development of an index based on a national AI strategy. Above all, it becomes clear that complex methodological problems must be addressed in the development of such an index. This de-

39 Further notes on important trends can be found in the CBInsights Report on 100 AI startups, "AI 100: The Artificial Intelligence Startups redefining Industries"
https://www.cbinsights.com/research/artificial-intelligence-top-startups/

bate must begin with the question of what should be understood by and subsumed under the term "AI". Based on this, we must clarify what we ultimately wish to measure in the AI field, and which indicators would be best suited to that task. Finally, we must engage openly and critically with the strengths and weaknesses of the indicators. As per our methodological classification model, this path would correspond to an indicator-driven approach.

There are good reasons why there is no indicator-driven approach in our overview. Such an approach would be extremely costly. There is also a risk that, while such an approach may produce very good indicators, those indicators cannot be practically implemented in terms of data collection and analysis. The approaches discussed here may suffer from methodological weaknesses, but they also demonstrate how valuable insights about various aspects of the field of AI can be gained through the deployment of limited resources and the use of existing data that is in many cases publicly available. There is no alternative to a pragmatic approach to the development of indicators. It is entirely legitimate to draw on existing data sources or to rely on surveys for certain questions, as long as one critically examines the validity of the sources and interprets the outcomes accordingly. Indicators are important tools for assessing development trends. However, they must be constantly, critically questioned.

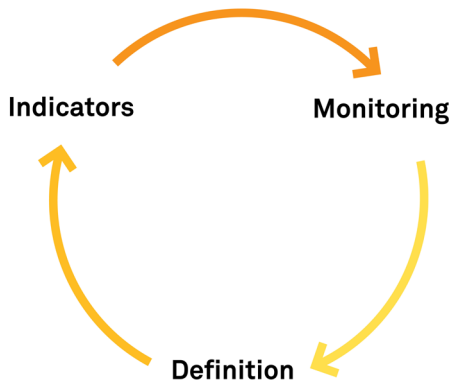
Ideas for the empirical foundation of the German AI strategy

None of the national AI strategies we examined systematically deals with the definition of clear goals and the resources and policy measures (input indicators) needed to achieve them. Also unanswered is the question of how the effectiveness of these measures (output indicators) can be monitored and validated. Germany can stand out positively here, if the government integrates the development of an AI index into its strategy. Based on our analysis as set out in the previous two chapters, we outline here some of our own ideas for developing an AI index. The key points of a national AI strategy, published by the Stiftung Neue Verantwortung, serve as a starting premise.[40] In this paper, we propose that the government's AI strategy should focus on the development of a strong AI ecosystem. Such an ecosystem is characteri-

40 https://www.stiftung-nv.de/de/publikation/eckpunkte-einer-nationalen-strategie-fuer-kuenstliche-intelligenz

sed by strong networks and close cooperation between science, economics, society and politics.[41]

We see the development of indicators for capturing the various dimensions of the AI ecosystem as constituting just one of three areas of action. However, it would be central to the empirical foundation of the AI strategy. This empirical foundation should, as shown in Graph 4, be an ongoing process. The starting point should be an analysis of the definition of AI, particularly regarding which areas of research and applications should fall under this definition. Based on this, the goals of the AI strategy and the measures for achieving them can be formulated. As discussed above in more detail, it is crucial to distinguish between input and output indicators. The input indicators either belong in the AI strategy or should at least be closely tied to it. They should lay out as concretely as possible the measures derived from the strategy, as well as the resources that are to be made available for their implementation. The output indicators are, by contrast, the clearly defined objectives of the strategy. They therefore form the basis for the definition of benchmarks, the achievement of which can be verified with the aid of indicators. Alongside the pursuit of input and output indicators, AI technology monitoring should be embedded into the process. This monitoring would serve to provide a current overview of important, global AI trends, and to quickly identify new developments that are relevant to the AI strategy.



Graph 4: Empirical Foundation of the AI-Strategy. Source: Stiftung Neue Verantwortung

41 An example of an attempt to examine the Canadian AI ecosystem http://www.jfgagne.ai/canadian-ai-ecosystem-2018-en

The three domains of an empirical foundation for an AI strategy interact with and stimulate one another. Input and output indicators derive from an analysis of what distinguishes a strong AI ecosystem. AI does not just subsume a multitude of research approaches; the field is itself developing very dynamically. Trend and technology monitoring supports the government's ability to identify new trends at an early stage. These findings should feed into the further development of the AI strategy, the definition of AI and the associated input and output indicators. This comprehensive approach can prevent the AI strategy from becoming a mere declaration of intent. The empirical foundation would turn the AI strategy into an AI strategy process that does not only involve the clear definition and implementation of measures, but that is also able to react to new developments and adjust according to the measurable results of the strategic process.

Input indicators

Input and output indicators can be clearly differentiated at a conceptual level, but in practice both are mutually dependent and derived from the same overall understanding of the AI ecosystem. In order to clearly describe the scientific, social, economic and political dimensions of this ecosystem, it is essential to address a definition of AI and the applicability of the term in specific research and application fields. There are good reasons why all AI strategies work with a very broad understanding of AI. After all, it is a research field that combines many different disciplines (computer science, cognitive sciences, statistics, etc) and that develops very dynamically. However, clear goals cannot be defined and their achievement cannot be validated without a clear understanding of which research approaches and applications fall under AI.

AI Applications	Examples for Applications
Predictive Analytics	• Control and maintenance of production facilities based on sensor data, allowing to react proactively to critical conditions that might result in malfunctions such as overheating. • Planning supply needs according to market changes
Optimized Ressource Management	• Optimize production and fabrication plans • Plan human ressources • Optimize logistic processes
Quality Management	• Testing components or other production elements • Controlling production and assembly via video-, picture-, or sensor-data.
Intelligent Assistance Systems	• Assistance with administration processes • Assistance in assembly • Support in production • Support in qualification and training
Knowledge Management	• Management of internal information and processes of the company • Data models for complex engineering processes • Configuration and description of interfaces between different components and products
Robotics	• Adaptive, learning industrial robotic systems in production • Adaptive service robots • Learning, self regulating assembly robots or grapplers
Autonomous Driving and Flying	• Driverless transport systems such as cleaning robots or autonomous drones to load shelves in warehouses
Intelligent Automation	• Automating routines in production and assembly by adapting self-regulating parameters • Automating production in IT-supported processes within the company (Robotic Process Automation), including decisions formerly made by humans, such as answering customer inquiries
Intelligent Sensor Systems	• Perception of surroundings (Picture, Laserscan) and pre-processing data to avoid collisions with driverless transport vehicles • Pre-processing data for monitoring production facilities

Table 7: Overview on AI applications and examples. Source: Institute for Innovation and Technology (itt), translation by authors

By way of example, an overview of AI applications developed by the Institute for Innovation and Technology (itt) is presented here. In a study for the Federal Ministry for Economic Affairs and Energy, the itt examined the potential of AI for the manufacturing industry. It therefore had to determine which AI technologies would fall within the scope of the study. In this table, the authors of the study provided an overview and listed the most important AI technologies. For each technology, they briefly described the associated procedures and methods. This sort of operationalisation of the term "AI" is also necessary for the development of input and output indicators. It would otherwise remain unclear to what they actually refer to.

The table below lists initial ideas for input and output indicators for each dimension of the AI ecosystem. In terms of research, the AI strategy should enumerate funding sums and describe how funding programmes could be made more agile, less bureaucratic and more competitive. It should include measures, as concrete as possible, for delivering AI skills across the entire educational system. Input indicators regarding the improvement of data provision include both the further development of the open-data approach and measures that could facilitate the exchange of data across different companies and sectors. With AI infrastructure, the key is using monitoring to quickly identify and address potential problems with access to important AI hardware. Economic input indicators could include, for example, special support programmes for the public purchase of AI systems. Input indicators in the social dimension could pertain to the strengthening of dialogue with civil society, and support for the research of ethical issues and the impacts of AI on work and employment. At the international level, important input indicators could include the establishment of transnational research cooperation and foreign policy initiatives for the development of international norms.

Subject Area	Input Indicators	Output Indicators
Research	Broken down according to application oriented and basic research - Financial resources - Agile funding programs	Broken down according to application oriented and basic research - Number of scientists in AI research - Number of doctoral students or doctorates - Number of conference participations, publications and citations - Attractiveness of the research location - Agility of research policy
Skills	- Teaching basic knowledge in primary education - Incorporating AI knowledge into university education - AI-relevant on-the-job training opportunities	- Dissemination of basic AI skills beyond R&D - e.g. at universities of applied sciences or in companies - AI modules within STEM
Data	- Access to data (Government: Open Data/ Economy: Data Pools) - Improvement of data quality and depersonalization procedures - Standardization of data formats	- Germany's progress in international open data indices - Dissemination and use of data pools
Infrastructure	- AI hardware technology monitoring - Promote strategically important AI hardware development - Acessibility of AI-linked cloud infrastructures	- Findings from hardware technology monitoring - Tracking of the most important hardware suppliers and their market shares - Market shares in AI hardware developed in Germany
Economy	- Promotion of programs designed for small and medium enterprises - Public AI-focused venture capital funds or measures to promote private investments in AI - Government Procurement	- Amount of AI investments in the economy (both investments in own projects and competencies and the purchase of AI startups) - Degree of use of AI in different industries by company size - Number of AI patents - Number of funded labs, and companies reached by these measures - Number and performance of AI startups - Venture capital investments in AI - Number of AI-focused accelerator programs and innovation labs

Subject Area	Input Indicators	Output Indicators
Society	- Engaging civil society in the political debate - Promote research on ethical principles and regulation and, if necessary, put them into law - Investigate the impact of AI on employment	- Outreach to civil society for example invitations to conferences, workshops and expert panels -Promote research on ethical and social issues around AI - Public relations around AI or surveys on the state of knowledge in the broader population - Research results on the impact of AI on employment
International	- Promote cooperation with other countries and the EU (e.g. through joint research projects) - Contributing to international standards on AI - Put AI on the foreign policy agenda	- Number of international research collaborations - Strategic AI investments of German companies abroad - Foreign Office activities on key international debates around AI - Progress in the development and implementation of the EU's AI strategy

Output indicators

Output indicators provide hints as to the particular dimensions of the ecosystem. If the output indicators are collected regularly over a longer period, they can also inform claims about the ecosystem's development. While input indicators can be relatively clearly defined by the government and do not require their own data collection, questions of methodology, data sources and significance play an important role in the development of output indicators. This is where the challenges and problems identified in the previous chapter on AI indices must be taken into account, in order to develop and correctly interpret usable output indicators. A critical approach to the methodology is needed in order to constantly re-evaluate and question the results. Indicators give us pointers about the overall picture and important developments. However, in the light of the aforementioned problems and limitations, they must not be blindly trusted and acted upon.

The measurement of research output remains controversial in science. Nevertheless, there are important metrics for evaluating the scope and quality of research activities. A first pointer lies with the number of people working in AI research. Researchers' output can be assessed on several levels: the number of doctoral candidates or successfully supervised doctorates, the number of presentations at leading AI conferences, and the sum and visibility of research publications (as ascertained by, for example, the number and quality of citations). The attractiveness of a research location could be determined by the number of scientists recruited from leading overseas institutes and universities, or by surveys of AI experts. One could also use surveys to examine and evaluate the biases and execution of research funding programmes' application procedures.

An important challenge described in our strategy paper is to not only foster AI skills in cutting-edge research, but to broaden them. Here one might, for example, list which technical colleges teach relevant skills for AI, and how many students will be reached. The teaching of AI-relevant competencies in STEM courses should also be covered. New data does not necessarily need to be collected in order to measure progress in open data. Instead, Germany's performance could be deduced from existing indices such as the Open Knowledge Foundation's Global Open Data Index.[42] Regarding the private-sector availability of data, it would be helpful to collect and analyse data pools that have been jointly initiated and used by various companies. In the field of hardware, output indicators would track progress regarding

42 https://index.okfn.org/

development and implementation of an AI hardware technology monitoring. Successful implementation would provide data about the most important hardware vendors and their market shares. From this, conclusions may be drawn about the levels of dependency and risk associated with access to critical hardware components.

The development and use of AI in German industry could be recorded and tracked across a range of indicators. The limitations here arise mainly through the effort needed to collect and evaluate data. It is not only the level of government funding of AI that is relevant, but also the investment of German industry. The level of AI development and application in businesses is probably most easily captured through surveys. It would also be important to survey how many people in a company are involved in AI-related activities. Survey results on the use and scale of potential state support programmes, such as proposed laboratories and experimental spaces for SMEs, would also be important. Activities in the startup sector must also be systematically recorded. In addition to the numbers of new businesses and exits and the extent of investments, size (employee numbers) and perhaps international connections (for example regarding investors or market activities) could prove interesting.

Social and international dimensions should also be taken into account with output indicators. Both tend to fall into the background during discussions about national AI strategies, which usually focuses on research funding and industrial policy. However, they are crucial to the success of an AI strategy. Indicators should therefore systematically cover the inclusion of civil society in the government's various AI-related discussion formats (for example, statistics of civil society organisations' involvement in dialogue and exchange formats). Furthermore, concrete benchmarks would be important for the funding of research projects that focus on the ethical and social aspects of AI. Large, representative surveys could record citizens' understanding, hopes and concerns around this new technology. At the international level, the focus should be on recording German research and industry's cross-border connections. The Federal Foreign Office's activities regarding the development of international standards could also be captured. And finally, the success of Germany's AI strategy will depend on how well national approaches are integrated into an EU-wide strategy. This requires assessment of progress in the planning, financing and implementation of concrete EU-wide measures and funding programmes.

The development of output indicators should be linked with a fundamental analysis of the underlying data, as the German state already collects a great

deal of relevant data and statistics. Rather than setting up entirely new data-collection procedures, it would in many cases be possible to make rapid progress by adapting existing statistical surveys and integrating categories that are relevant to the AI strategy.

AI technology and trend monitoring

The input and output indicators should also be accompanied by AI technology and trend monitoring. The introduction of technology monitoring is also mentioned in the government's outline paper, albeit without providing any details. Such monitoring makes a lot of sense, in both research and application, as AI is both a very broad field and a very dynamic one. New research approaches have been established very quickly in recent years, and there is rapid development in applications of the technology. Thus it makes sense to adopt as broad and open a definition of AI as possible. However, for the purposes of operationalisation there should be a clear understanding of which research approaches and fields of application fall under AI and should therefore be analysed in more depth.

Continuous trend monitoring does not only serve to quickly detect new developments, but can also be used to keep the operationalisation of indicators up-to-date and relevant, for example by adding new fields of research. The evaluation of existing trend reports, such as the above-mentioned CBInsights Trend Report or the State of AI presentation could serve as a basis. Resources permitting, an evaluation of existing reports could be expanded through fresh data collection and analysis. In this way, new data collection and evaluation of the most important performance competitions and challenges in the field of AI could provide crucial information about research developments. Other important topics for AI trend monitoring include the implementation of AI applications in various industries and the associated impacts on value chains. In addition, surveys of leading national and international AI experts offer the opportunity to identify the latest trends and developments.

Outlook

With the publication of its key points for a national AI strategy, the German government is following the example of numerous countries that have already published national AI strategies. Our analysis shows that these strategies are ambitious but ultimately imprecise. Clearly defined targets are missing, as are input and output indicators that determine measures to be taken and the available resources, as well as concrete benchmarks for implementation. Germany has an opportunity here to do better. Focussing the discussion on the implementation of clearly defined goals, and the success criteria that are necessary for this purpose, can only benefit a societal discourse that is for now overly broad. The analysis of existing AI indices reveals the hurdles and challenges that need to be overcome.

Given the level of expenditure that is expected for the implantation of the AI strategy, the budget needed for setting up monitoring and benchmarking is relatively modest. It would be money well spent, though. Only if the development of a German AI ecosystem is accompanied by indicators, we will have reference points for the evaluation of measures developed under the strategy. Ultimately, it is not possible to achieve an agile and goal-oriented implementation of the AI strategy without an empirical foundation. The government should commission an independent research institute to develop such a measurement approach. The institute would primarily develop and record the output indicators, on the basis of scientific standards and high methodological competence, and prepare the AI trend report. The research institute should be able to operate freely and independently of political influences. Defining the input indicators, however, is a political task. Only the government and parliament can decide on the allocation of budgetary funds and the development and implementation of policy measures.

Regularly published reports from a commissioned research institute, with data on specified indicators regarding the development of the German AI ecosystem as well as global trends, would provide an empirical basis for the socio-political discussion around AI in Germany. In addition, the reports would give the government an important resource for the successful implementation and continuous development of the national AI strategy. Of course, the government itself will need to be evaluated in the reports. This is not entirely without political risk. However, the willingness to take this risk would send a very strong signal: that the government is serious about implementing its AI strategy.

About the Stiftung Neue Verantwortung

The Stiftung Neue Verantwortung (SNV) is an independent think tank that develops concrete ideas as to how German politics can shape technological change in society, the economy and the state. In order to guarantee the independence of its work, the organisation adopted a concept of mixed funding sources that include foundations, public funds and businesses.

Issues of digital infrastructure, the changing pattern of employment, IT security or internet surveillance now affect key areas of economic and social policy, domestic security or the protection of the fundamental rights of individuals. The experts of the SNV formulate analyses, develop policy proposals and organise conferences that address these issues and further subject areas.

About the Authors

Dr. Stefan Heumann is member of the management board of Stiftung Neue Verantwortung (SNV) and a political scientist. He is a member of the German Parliament's Expert Commission on Artificial Intelligence.

Nicolas Zahn studied political sciences and worked at the SNV in July 2018 as part of his Mercator Fellowship on international affairs.

How to Contact the Authors

Dr. Stefan Heumann
Member of the management board of Stiftung Neue Verantwortung
sheumann@stiftung-nv.de
+49 (0)30 81 45 03 78 80

Imprint

Stiftung Neue Verantwortung e. V.

Beisheim Center
Berliner Freiheit 2
10785 Berlin

T: +49 (0) 30 81 45 03 78 80
F: +49 (0) 30 81 45 03 78 97

www.stiftung-nv.de
info@stiftung-nv.de

Design:
Make Studio
www.make-studio.net

Layout:
Johanna Famulok

Free Download:

www.stiftung-nv.de