Making AI work in The Netherlands

Zuid-Holland as hub for Data Science & Artificial Intelligence in the Netherlands

InnovationQuarter & Birch Consultants 2020

Colofon

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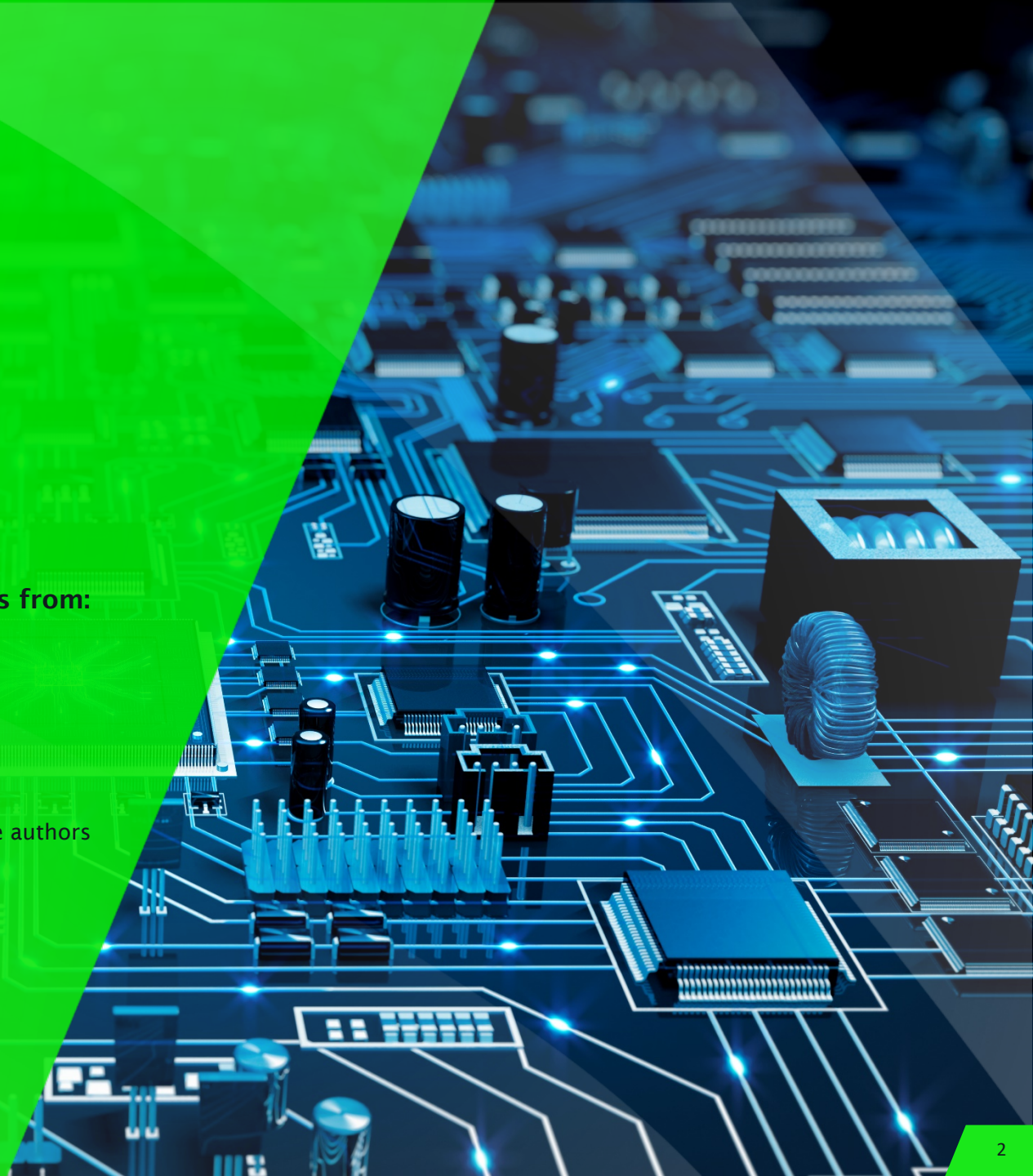
Many thanks to our steering committee with representatives from:

- TU Delft
- Leiden University
- Erasmus University
- ORTEC
- VORtech



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Developing AI: an opportunity for The Netherlands and Zuid-Holland

- The Dutch government published its national AI strategy in 2019 and has gained follow-up from a National AI Coalition. This coalition consists of knowledge institutes and private sector companies. These organisations have taken the responsibility to formulate further strategic actions and invest in new AI capabilities along the lines of human capital development, research and innovation, data-sharing, societal inclusion and entrepreneurship. This action plan requires regional organisations to be aligned with the national strategy, providing support to start-ups, advising small and medium enterprises, setting up collaborations to share data and knowledge and attracting new AI talent and activity to the region.

- These developments will require carefully placed public and private investments. There is ample opportunity for innovation and value creation when these strategies are successfully executed. However, there is stiff international competition from the rest of Europe, the USA and China, all intent on becoming frontrunners in AI technology driven economic growth. In this competitive environment the Netherlands must ascertain a leading position by making the right investment choices.

- This raises the issue of how The Netherlands positions itself, and how within The Netherlands different regions can contribute. Specifically, this report looks at the contribution of Zuid-Holland in the Dutch innovation ecosystem. We will answer two main questions:

  How should Zuid-Holland position itself within the Dutch AI ecosystem?
  How can InnovationQuarter and its regional stakeholders contribute to enhancing AI developments in The Netherlands?

- To answer these questions the report starts with providing a deeper explanation of Data Science & AI. This will be followed by an overview of the regional innovation ecosystem for AI in Zuid-Holland and an analysis of market potential in six leading economic sectors. The last chapter will conclude with strategic recommendations for InnovationQuarter and its stakeholders.

Data Science & AI: a deeper explanation

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Definition of Artificial Intelligence

The boundaries of AI and between Data Science and AI are fuzzy

Artificial Intelligence is hard to pin down as a concept. Most definitions of AI are constructed with similar elements. For example, both definitions below suggest that AI is a technology that is **responsive** to its environment and **learns** from it whilst being relatively **autonomous**.

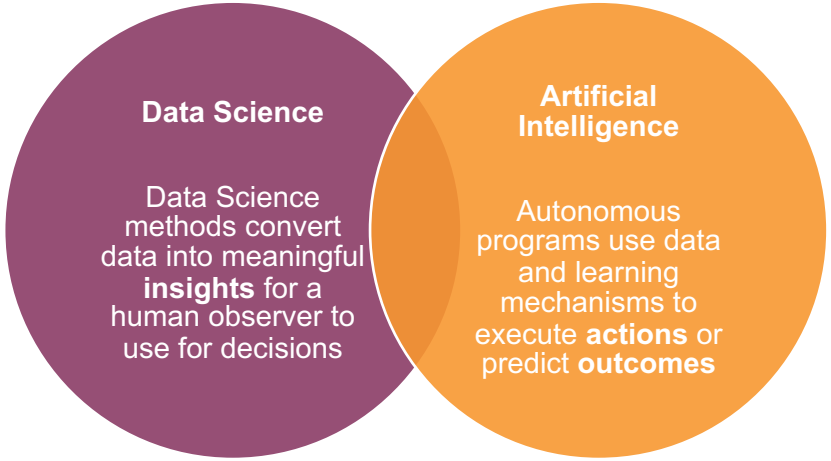
"Artificial Intelligence' (AI) can be used to indicate any technology (software, algorithm, a set of processes, a robot, etc.) that is able to function appropriately with foresight of its environment" - N. J. Nilsson [1]

"Artificial intelligence (AI) refers to systems that show intelligent behaviour: by analysing their environment they can perform various tasks with some degree of autonomy to achieve specific goals" - European Commission[2]

However, *"AI is not a well-defined technology and no universally agreed definition exists".*[3]

To tackle this, in this report we refer to AI as a collection of **approaches** and **technologies** that are capable of achieving business **goals**, and what innovation **frontiers** there currently are that challenge work towards these goals. Here we summarize these topics to provide a good understanding of the spectrum of AI.

A first distinction to make is the difference between **Data Science** and **Artificial Intelligence**. A good way to distinguish between these concepts is to examine their end-products.



This distinction is not without overlap. Data Science methods are often used in designing models for AI and AI applications often do have humans in the loop. In practice, the distinction is too vague to be of use. Instead, we will note when a company or industry leans more to either Data Science (insights) or Artificial Intelligence (actions and outcomes).

[1] Nilsson, N. J. (2009). The quest for artificial intelligence.
[2] European Political Strategy Centre (2018). The Age of Artificial Intelligence – Towards a European Strategy for Human-Centric Machines
[3] European Parliament (2018) European Artificial Intelligence (AI) leadership, the path for an integrated vision.

Requisites for Artificial Intelligence

New AI approaches are primarily fueled by processing power and data

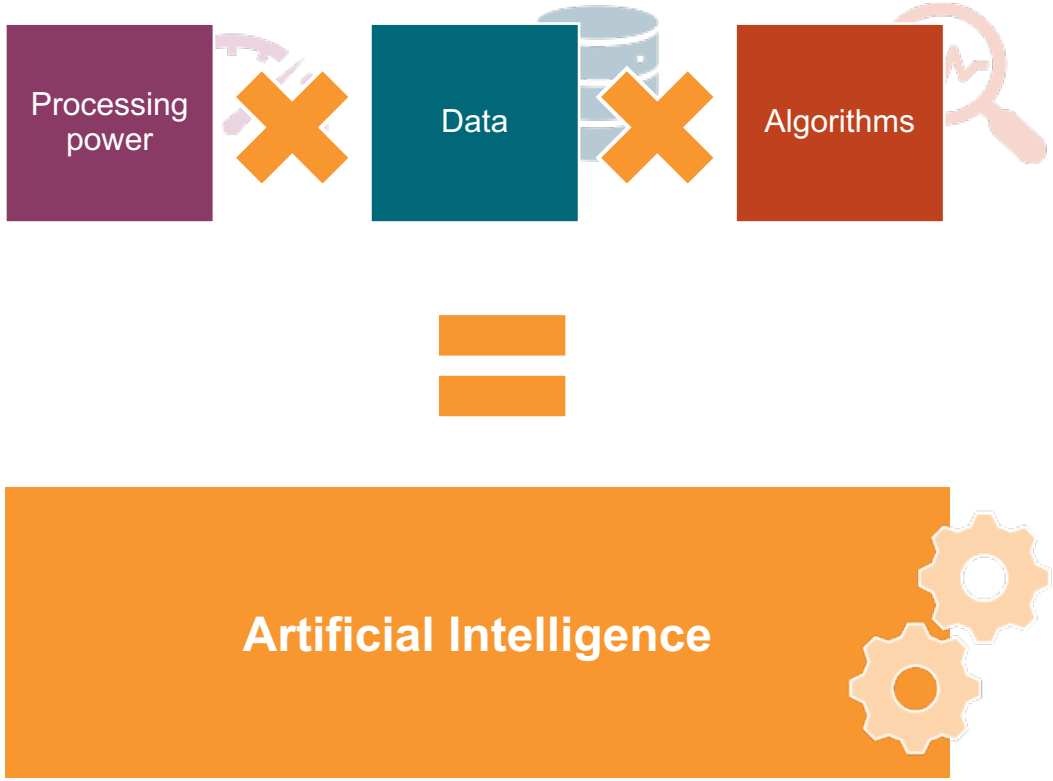
AI technologies require three crucial elements in order to be successful.[1]

1. **Processing power:** More computing power and storage at reasonable costs enable AI to process more complex calculations in less time.

2. **Data:** An increase in the amount of available high-quality (annotated and labelled) data fuels the viability and usefulness of algorithms.

3. **Algorithms:** The rules by which an AI program operates. Innovation in algorithms accelerates AI developments and enables new possibilities.

The biggest differentiators in recent AI innovations are not algorithms, but fast growth of processing power and the sharp increase in available data



[1] McKinsey & Company(2018). An executives guide to AI. Retrieved from https://www.mckinsey.com/business-functions/mckinsey-analytics/our-insights/an-executives-guide-to-ai

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Algorithm approaches

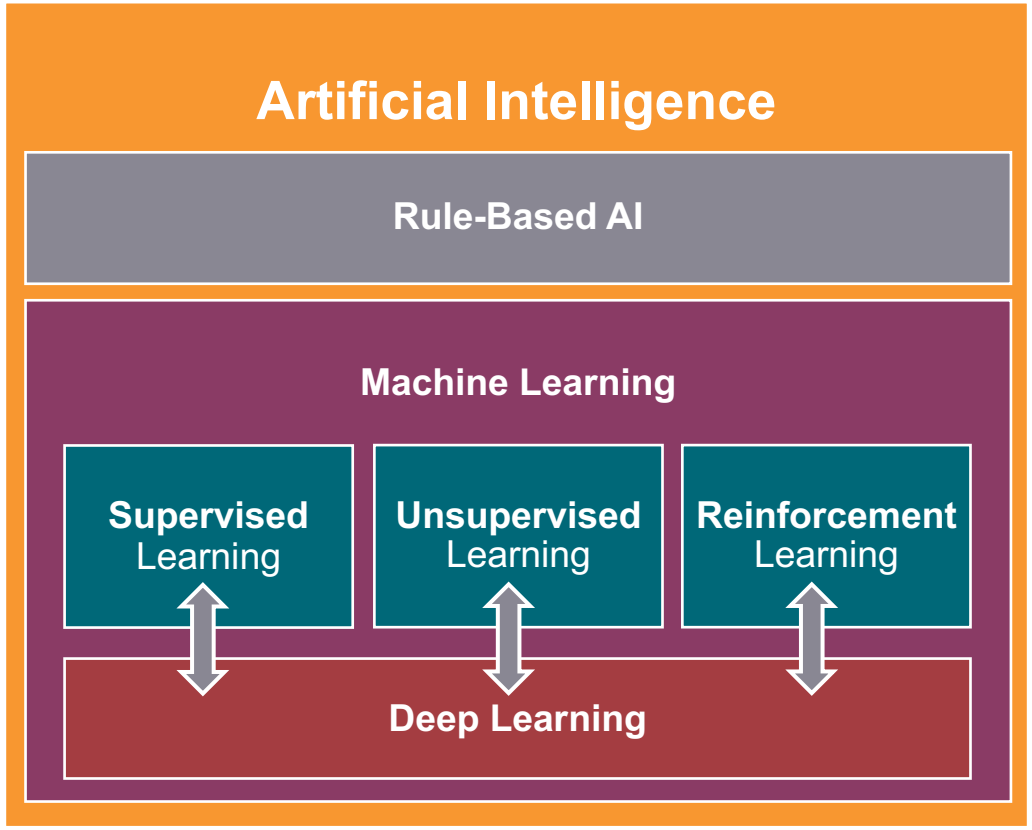
Today's AI is driven by Machine learning

Traditional algorithms are described as **Rule-Based**. Systems based on these algorithms get input and follow a set of *pre-defined* rules and instructions to generate output.
The current uptake in AI is largely due to the application of **Machine Learning**[1] algorithms, whose performance change by exposing them to more data over time. These algorithms make use of (dynamic) input in order to derive machine-made patterns from the information and translate these to insights and actions.

Types of Machine Learning-Based AI:

- **Supervised Learning:** Labelled data by a human is put through an algorithm that models the relationships between each label and the input values.
- **Unsupervised Learning:** Unlabelled data is put through an algorithm that identifies rules, detects patterns, and summarizes and groups data points to derive insights.
- **Reinforcement Learning:** An autonomous, self-teaching system learns by trial and error to achieve the best outcomes. It performs actions aiming to maximize rewards.

Deep Learning: highly complex subset of Machine Learning that uses algorithms that mimic the neural network of the brain, to progressively extract higher level patterns and learn from vast amounts of (un)labelled data.
Recently developments in Deep Learning have outperformed humans and classical computers at achieving several **goals**, such as winning complex games (GO, Starcraft), text translation (Google Translate) and classifying radiology images.



[1] Fumo, D. (2017). Types of machine learning algorithms you should know. Retrieved from: https://towardsdatascience.com/. The frontiers of AI research that use these novel types of algorithms are described in the Appendix.

Business goals of Artificial Intelligence

AI approaches often show one or more goal patterns

AI approaches often show one or more of these goal patterns.[1]
Example: a self-driving car uses an Autonomous System as operating system, with a Goal-driven System to determine the car's path and a system using Recognition and Anomaly detection to detect objects around the car and possible additional hazards.

- **Hyper-personalization:** goal is to develop unique profiles of individual users that are adaptable over time for a variety of purposes. *Example: a credit scoring system that looks at each individual's personal credit history and uses it to create a personalised score.*
- **Goal-Driven Systems:** goal is giving a system the ability to learn the optimal solution to a problem through trial and error. *Example: A system learning to win a game of chess through thousands of games.*
- **Autonomous Systems:** goal is to accomplish a task in an environment with little to no human involvement, minimising human labour. *Example: The operating system of a self-driving car.*
- **Predictive Analytics & Decision Support:** goal is to help humans make decisions through applications which suggest actions and predict future outcomes learned through data. *Example: Using machine learning-based regression to predict failures in the electrical grid.*
- **Human Interaction:** goal is to interact with humans with conversation through voice or text. *Example: A chatbot interpreting messages and generating responses.*
- **Pattern & Anomaly Detection:** goal is to identify patterns in data and learn connections between variables that provide insight into whether given data fits an existing pattern or is an outlier. *Example: A fraud detection system at a bank classifying transactions as ordinary or anomalous.*
- **Recognition:** identify and understand unstructured content through segmenting and recognizing this content into something that can be labelled and structured. *Example: Facial recognition systems which can recognize the different curves and lines in a face as a pair of eyes, a nose, a mouth etc.*

[1] Cognilytica (2019). The Seven Patterns of AI. Retrieved from https://www.cognilytica.com/2019/04/04/the-seven-patterns-of-ai/

Technology Readiness of AI in applications

The next decade is expected to be the *age of implementation*

The spectrum of AI applications is broad and many innovations are not yet in a state of maturity[1]. Depending on the underlying technology and the area of application, there is a **high variety of maturity**.

Currently, the supervised machine learning approach is providing the most value in the deployment phase for industries where data is plentiful and structured, and where there is little room for ambiguity or uncertainty.

Most new innovative applications are expected from other forms of machine learning, especially Deep Learning is expected to revolutionise the tasks computers are capable of.

The expectation is that the next decade will be an '**age of implementation**'[2]. However not all predictions and expectations about AI are realistic (see Appendix II)

Discovery	Development	Demonstration	Deployment
• *Several frontiers with technological challenges to overcome (see Appendix I)*	• Giving complex medical advice • Recognising emotions • Voice translation • Editing images • Predicting riots and protests	• Self driving cars • Generating an Image/voice/video • Legal reading and writing • Predicting crop yields • Formulate medical treatment plans	• Optimising energy consumption • Navigation advice for traffic • Optimising pesticide use • Diagnosing different cancers and pneumonia • Detecting malware • Text translation • Facial recognition

[1] An up to date list of AI achievements is kept at https://deepindex.org/. Examples here are primarily from this list.
[2] Kai-Fu Lee (2018) AI Superpowers. China, Silicon Valley and the New World Order

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Technological advancements call for ethical AI practices

With AI bringing new technologies and possibilities to the mainstream, questions arise about the fairness, transparency and responsible use of new algorithms and new sources of data. This requires both governments and international organisations to step in.

In April 2018, the European Commission put forward a European approach to Artificial Intelligence and robotics that deals with technological, ethical, legal and socio-economic aspects to boost EU's research and industrial capacity[1]. Goals are to make the EU a leading force in developing and operationalizing AI and to put AI at the service of European citizens and the economy. *"The EU can lead the way in developing and using AI for good and for all."* In June 2018, the High Level Expert Group on Artificial Intelligence (AI HLEG) was set up by the EC. This group prepared The Ethics Guidelines for Trustworthy AI[1]. This approach is referred to as **human-centric AI**.

There is a host of other (inter)national organisations that have published guidelines and requests for more responsible and humane use of AI technology. However, apart from the European General Data Protection Regulation (GDPR) there is no legal framework yet for AI and these ethics guidelines have no official legal status.

7 principles of trustworthy AI formulated by the AI HLEG

1. human agency and oversight
   - AI respects human autonomy
2. technical robustness and safety
   - AI is developed with a preventative approach to risks
3. privacy and data governance
   - AI protects data and processes it responsibly
4. transparency
   - AI is recognisable and its workings are traceable and explainable
5. diversity, non-discrimination and fairness
   - AI provides equal treatment and AI products are accessible by all
6. environmental and societal well-being
   - AI technologies are designed to be societally responsible
7. accountability
   - AI systems are auditable and minimise negative impact

[1] European Commission (2018), AI for Europe, DG Connect.
[2] High Level Expert Group on Artificial Intelligence (2019), The Ethics Guidelines for Trustworthy AI.

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Innovation ecosystem

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Key elements of the Zuid-Holland AI innovation ecosystem

For a strong AI innovation ecosystem, **public organisations, corporates, knowledge-institutes and entrepreneurs** should work together to further develop and implement AI and Data Science technologies. A well-functioning ecosystem would consist of several structural components that, when working properly, enhance opportunities for innovation and entrepreneurship.[1,2] For Zuid-Holland, we investigate the following components:

Startups & Capital

- The dynamics of new entrants onto the playing field leveraging AI and Data Science for use in existing industries.
- The ability of startups to scale and grow (by attracting investments).

Industry

- The dynamics of existing industry in adopting new AI and Data Science technology.
- The contributions of industry to research and development.

Research & Innovation

- The efforts of universities and knowledge institutes in developing frontier knowledge.
- The ability of universities to translate research findings to innovation in society.

Human Capital

- Dynamics in the supply of talent, people entering the labour market with AI related skills.
- Demand for AI talent in the region.

[1] Hekkert, Marko, et al. (2007). Functions of innovation systems: A new approach for analyzing technological change. *Technological Forecasting & Social Change* 74, pp. 413-431 & Stam, F. C., & Spigel, B. (2016). Entrepreneurial ecosystems. *USE Discussion paper series*, *16*(13).
[2] These components are also the basis for the strategic agenda in the Netherlands, see NL AI Coalitie (2019), Algoritmen die werken voor iedereen.

Frontier AI research and unique implementation opportunities

Zuid-Holland should be able to become a leading AI hub in the Dutch and European AI ecosystem. It combines a leading position in international AI research with great opportunties for implementation. The potential for economic- and societal impact in several leading Dutch industries is enormous. The region has **160 active startups and scaleups** with 4.300 employees (22% of The Netherlands), **large corporates** investing in AI, **three top universities and two medical centres** combining the efforts of **1.000 researchers** and a **fast growing talent pool** of students.

Start-ups & Capital

- AI startups in Zuid-Holland often choose to integrate AI knowledge with domain specialisation to cater to a specific vertical.
- VC investments in AI are on the rise in Zuid-Holland.
- There is an opportunity to scale more AI startups.
- Active cluster of AI startups in life sciences, which are succesful in attracting investment.

Industry

- AI is on the priority list of existing industry in Zuid-Holland.
- However, investments and serious expansions of AI staff are yet to follow.
- Most AI innovations are in pilot phase.
- Corporates make increasingly significant contributions to public-private research and development.

Research & Innovation

- Zuid-Holland has the capabilities and mass to generate a sizable amount of frontier knowledge for the innovation ecosystem.
- Research covers both fundamental advances and industry implementation, with sufficient knowledge available to do both.
- The region is well positioned for the upcoming European investments in AI.

Human Capital

- Growth of students in AI and related fields is fast. Limited capacity becomes a challenge.
- There is an opportunity to scale the available capacity at universities.
- Demand for AI talent exceeds supply, due to *brain drain* of qualified candidates and experience gap of new talent.

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Zuid-Holland has strong presence of AI startups in multiple industries

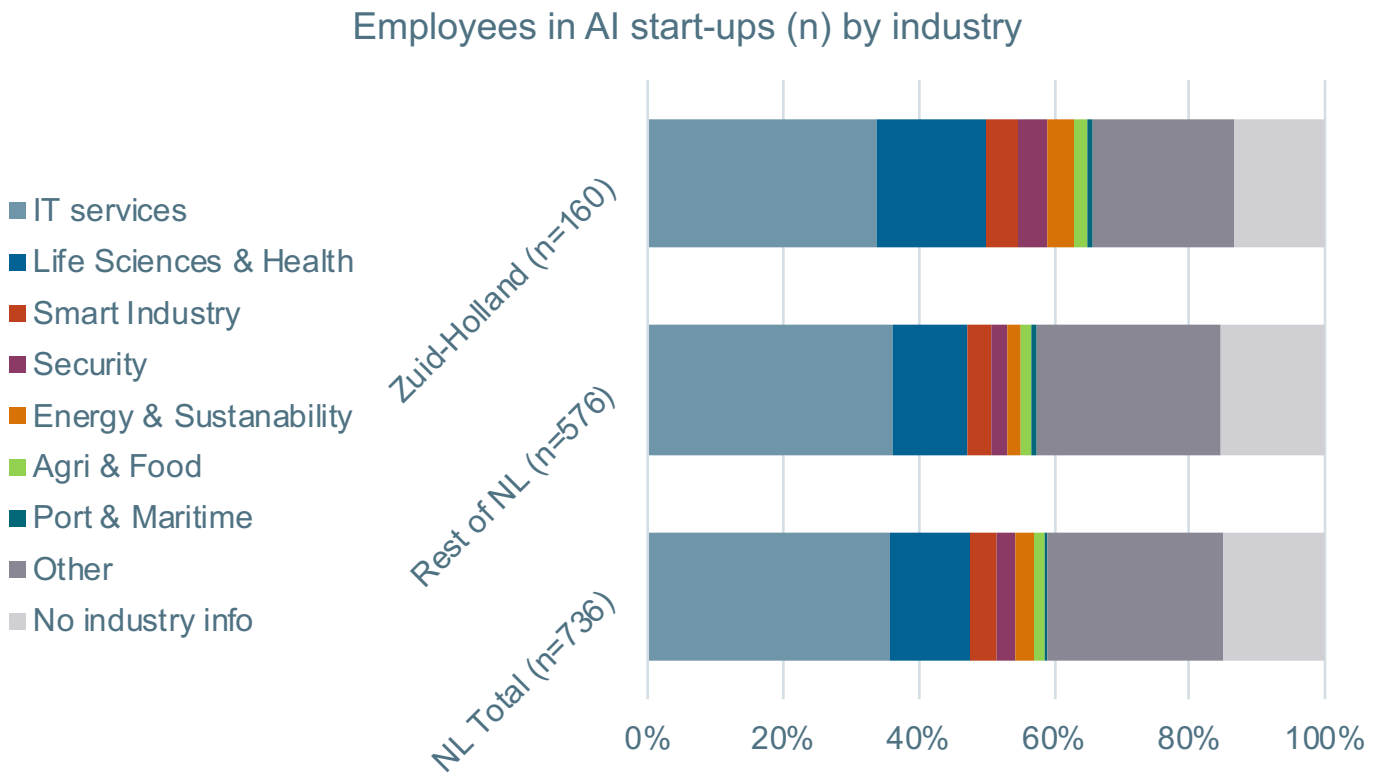
140+ startups & 16 scaleups[1]

4.300 employees

Rest of NL: 525 startups and 51 scaleups, 15.100 employees

A total of **±19.400 employees** with **AI startups and scaleups in the Netherlands** is active, of which ±4.300 **(22%)** at companies in **Zuid-Holland**.[1]

- Several vertical industries are represented relatively high in start-ups and scaleups in Zuid-Holland.
- Startups with specific industry focus comprise 32% of the AI-related employees in Zuid-Holland. Half of these employees are in **Life Sciences & Health related AI start-ups (1,4× of national average)**, .
- Other industries have less mass but illustrate the region's strong profile of AI startups in multiple industries: **Security (1,6×), Energy & Sustainability (1,6×), Smart Industry(1,2×)**



[1] Source: Data acquired from Dealroom and DataFox, see Appendix. Employee information was available for 736 companies (>1 employee) in the Netherlands of which 160 are in Zuid-Holland. Scaleups are companies with >50 and <151 employees. Estimate based partially on averages.

VC in AI grows 2× in 5 years; share Zuid-Holland increases

76 deals with 44 startups

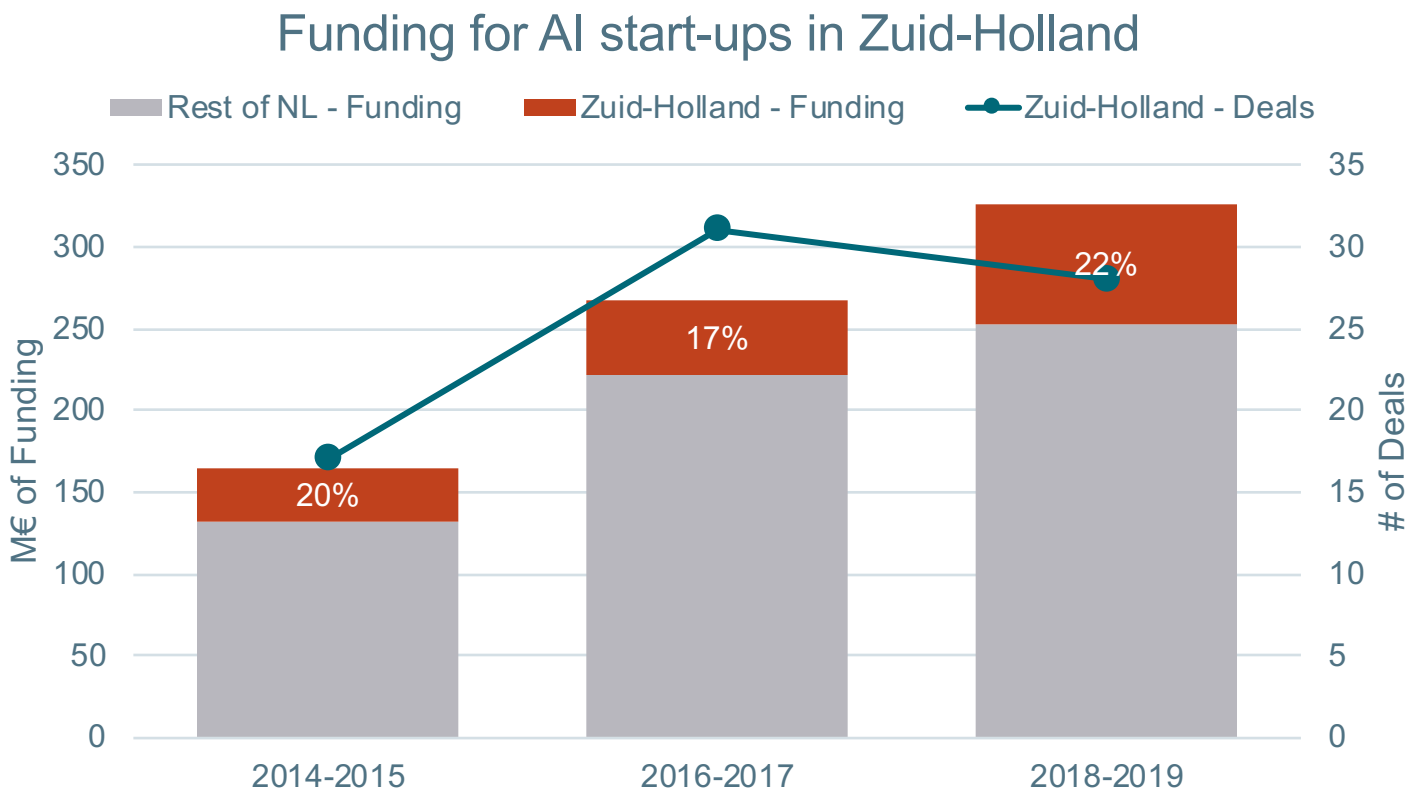
2,0 M€ avg deal volume

Rest of NL: 261 deals with 166 startups with avg 2,3 M€ volume

In 2014 through 2019, **disclosed investments worth 756 M€** were made **in 210 AI related companies in the Netherlands.**

- Of these companies, **21%** (44) were located **in Zuid-Holland,** collecting 151 M€ (20%) in 76 deals (29%).[1]
- The amount of funding in the Netherlands in AI companies increased from 165 M€ in 2014-2015 to 326M€ in 2018-2019 (2× growth). Noord-Holland consistently takes the largest share of investments, followed by Zuid-Holland.

2019 so far is a record year for Zuid-Holland in venture capital, with 46 M€ invested driven by several large volume deals.



[1] Source: Data acquired from Dealroom and DataFox, see Appendix. Data 2019 is incomplete. Only investment rounds with a known year and funding amount are taken into account.

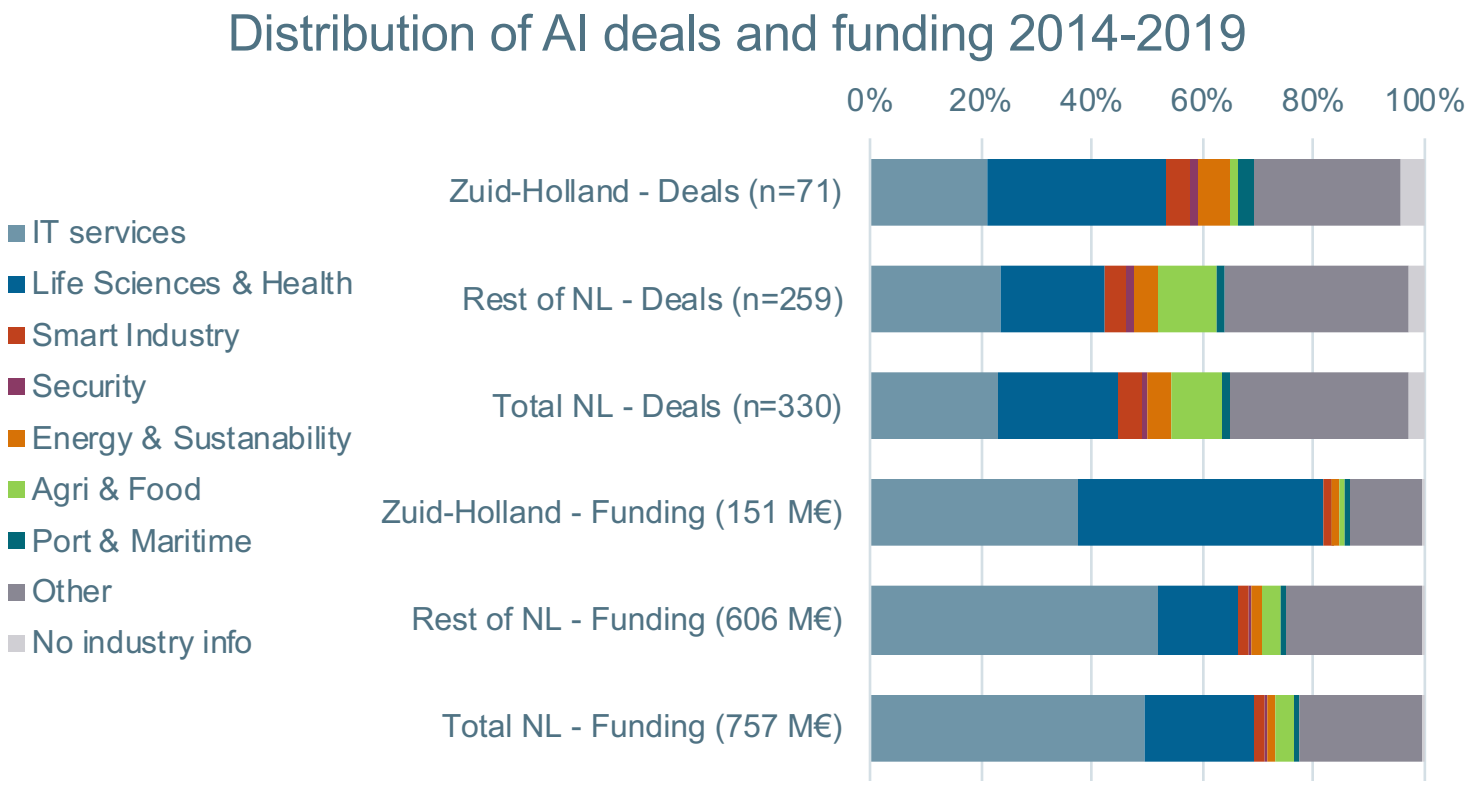
High VC concentration in Life Sciences & Health

Between 2014-2019 AI startups in Zuid-Holland acquired 150 M€ in funding.[1]

- Funding for **Life Sciences & Health** is more concentrated in Zuid-Holland with 61 M€ in 24 deals, which constitutes 42% of funding in this category.
- Industries like Agri & Food, Energy & Sustainability, Security and Port & Maritime are **underrepresented in funding** in Zuid-Holland because of low deal volume.

Only a third of Zuid-Holland startups attracts (disclosed) investments, suggesting that **other startups are bootstrapping without VC funding**.

- This is possible as AI-technology has relatively low barriers to entry. It only requires talent and some computing resources to design and build prototypes.
- However, it requires effective partnerships and funding to test and deploy these prototypes within industries.



[1] Source: Data acquired from Dealroom and DataFox, see Appendix. Data 2019 is incomplete. Only investment rounds with a known year and funding amount are taken into account. See Appendix.

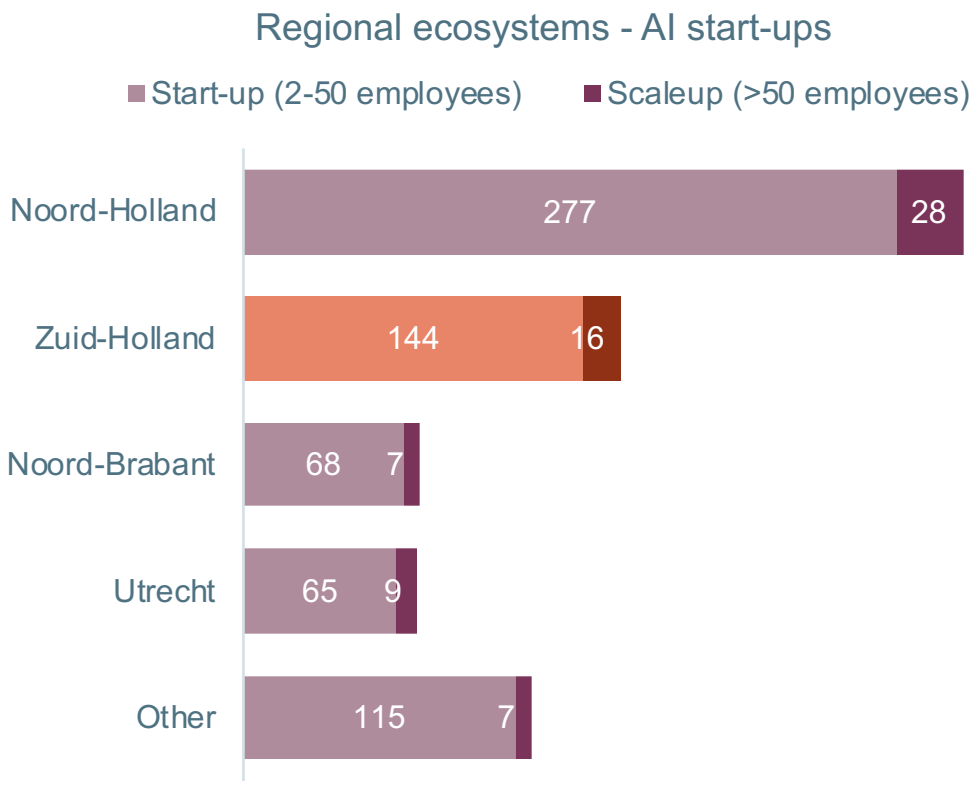
Dutch AI ecosystem could deliver more scaleups

Noord-Holland, with Greater Amsterdam, is the primary AI startup magnet in The Netherlands. **Zuid-Holland has the 2nd largest cluster of AI startups.**

Only 9% of these startups are seriously scaling (>50 employees). A multitude of startups with industry-changing ideas is not yet scaling, either because of barriers to entry in existing industries, lacking partnerships with incumbents or funding issues.

Relatively small investments are a known problem in European Tech. For AI specifically, The Netherlands suffers from the same European Paradox: compared to the US and East Asia there are **insufficient funds to scale**. Some Dutch startups even **consider moving their business to the US**.

- An average EU venture capitalist (60 M€) is half the size of an average US venture capitalist.[2]
- Europe is accelerating in tech investments. **AI investments increased 4×** between 2015 and 2019 (from 1,25 B€ to 4,9 B€) across Europe.[3]
- However, investments are still geographically concentrated to the top 5 cities (London, Berlin, Stockholm, Paris & Munich). Amsterdam is in the top 20 of ecosystems in Europe, but **investors need to widen their search** for new AI startups to enable other ecosystems to deliver more scaleups.



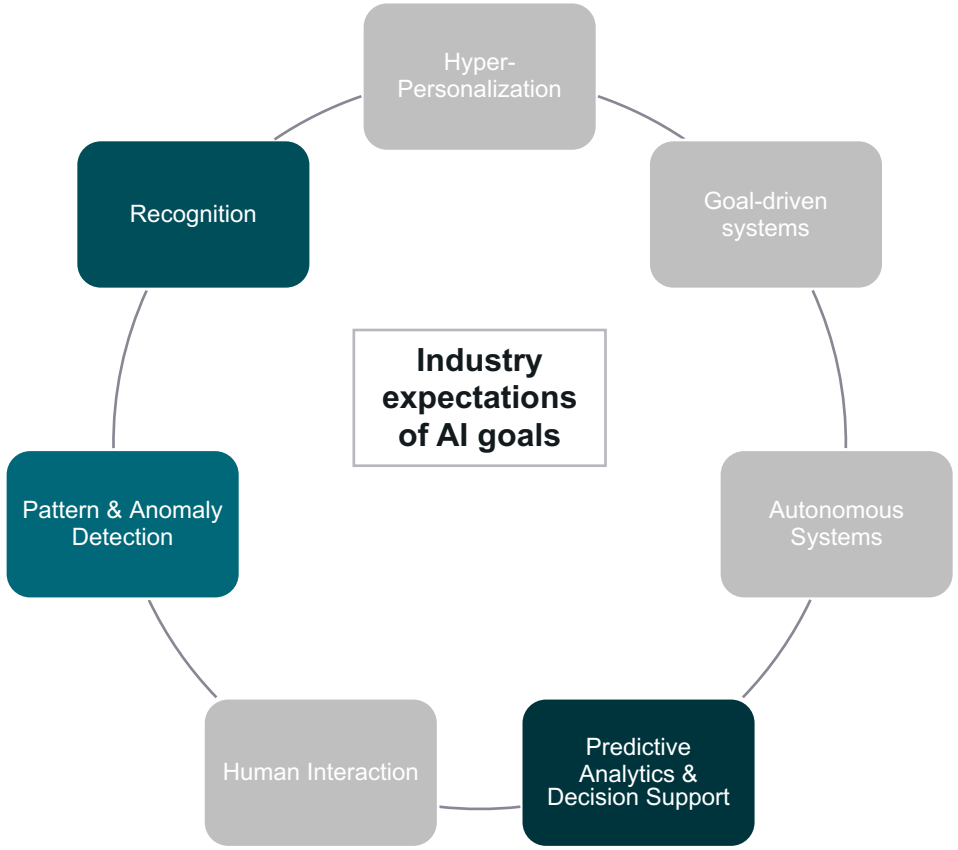
[1] Source: Data acquired from Dealroom and DataFox, see Appendix.
[2] Roland Berger (2019), The road to AI, Investment dynamics in the European ecosystem - AI Global Index 2019.
[3] Atomico (2019), The State Of European Tech.

Dutch industry sees importance of AI; investments yet to follow

Innovation in industry is important for the competitive advantage of Zuid-Holland. The region has a significant role in exports and an R&D investment above national average.[1] Corporates in established industries are following AI developments closely and recognise its opportunity.

- Proprietary activity on AI is still small. Even amongst industrial leaders with large R&D budgets, our estimate is that less than **0,5% of staff is developing or implementing AI solutions** in teams of 10-25 FTE [2].
- While current maturity in industries is low, 81% of Dutch executives expect **the impact of AI will be very high**.[3] This impact will firstly and mostly come from optimisation in existing processes, reflected in the goals most often named by R&D intensive companies (right).
- These companies face a ***make or buy* decision**: invest in implementing AI within the primary business process or find solutions built by specialised third party suppliers. Considering the size of most AI teams, industry is predominantly opting for the latter.
- In the long run this may lead to **innovation lags**, as innovation in AI is less likely to 'leak' to other organisations, with first movers taking advantage of trained algorithms.[4]

More detail on the specific AI efforts of industry in Zuid-Holland is provided in the Market Potential chapter.



[1] NEO Observatory (2018) Regiomonitor 2018.
[2] Team analysis based on interviews and ~10 responses from R&D intensive corporates in Zuid-Holland.
[3] AINED (2019), AI voor Nederland – Vergroten, Versnellen en Verbinden.
[4] Microsoft & EY (2019), Artificial Intelligence in Europe - Outlook for 2019 and Beyond.

Adoption of AI is increasing; R&D projects on the rise

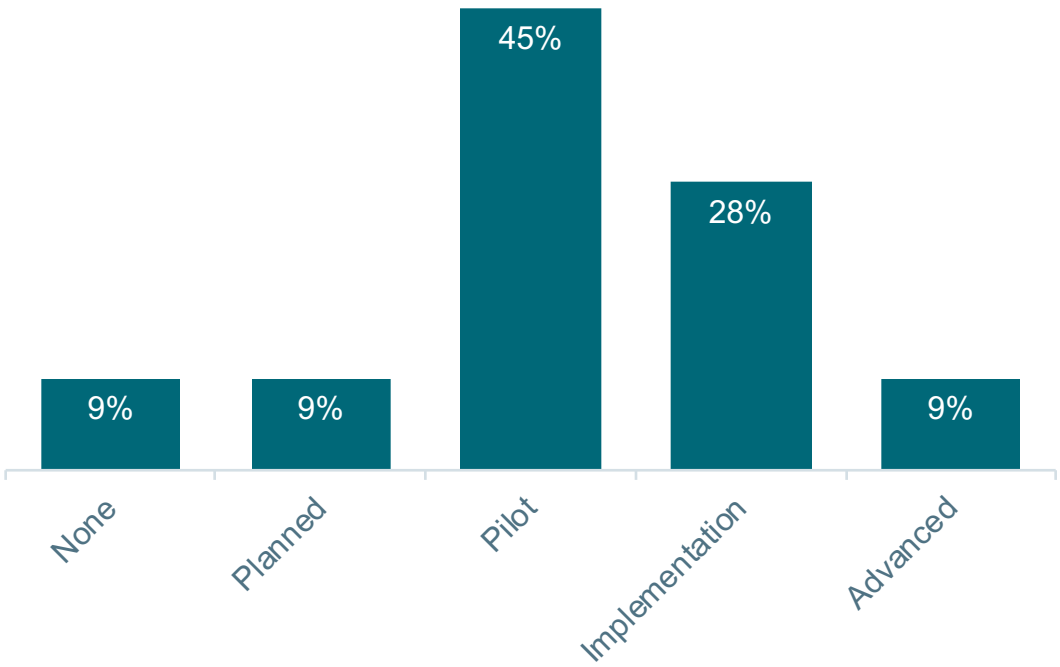
The adoption of AI by corporates is slightly increasing, with 45% of executives stating that pilot projects are in progress within their company. Additionally, corporates are investing more in the development of new AI solutions. This can be seen in the the formation of AI R&D projects, including:

- **Airlab:** This ICAI research lab is a collaboration between TU Delft and Ahold-Delhaize and focusses on developing innovations in the retail industry.
- **AI for Fintech Lab:** ICAI lab in which ING and TU Delft collaborate on performing research at the intersection of AI, data analytics and software analytics in the context of fintech.
- **Erasmus Centre for Data Analytics (ECDA):** centre for cross-disciplinary research and hands-on education on data and AI at Erasmus University Rotterdam established with Coolblue, Gemeente Rotterdam, ING, Siemens and Quint.
- **Robovalley:** Initiative to connect entrepreneurs, investors, researchers and other professionals working on robotics and AI innovations.

Additionally, ±20 companies in Zuid-Holland have attracted a total of 5,1 M€ in EC funding and ±320 European partner organisations for Research and Development.

There are planned expansions for ICAI labs and increasing activity in industry specific networks, see the chapter on Market Potential.

% of Dutch companies active in AI[1]



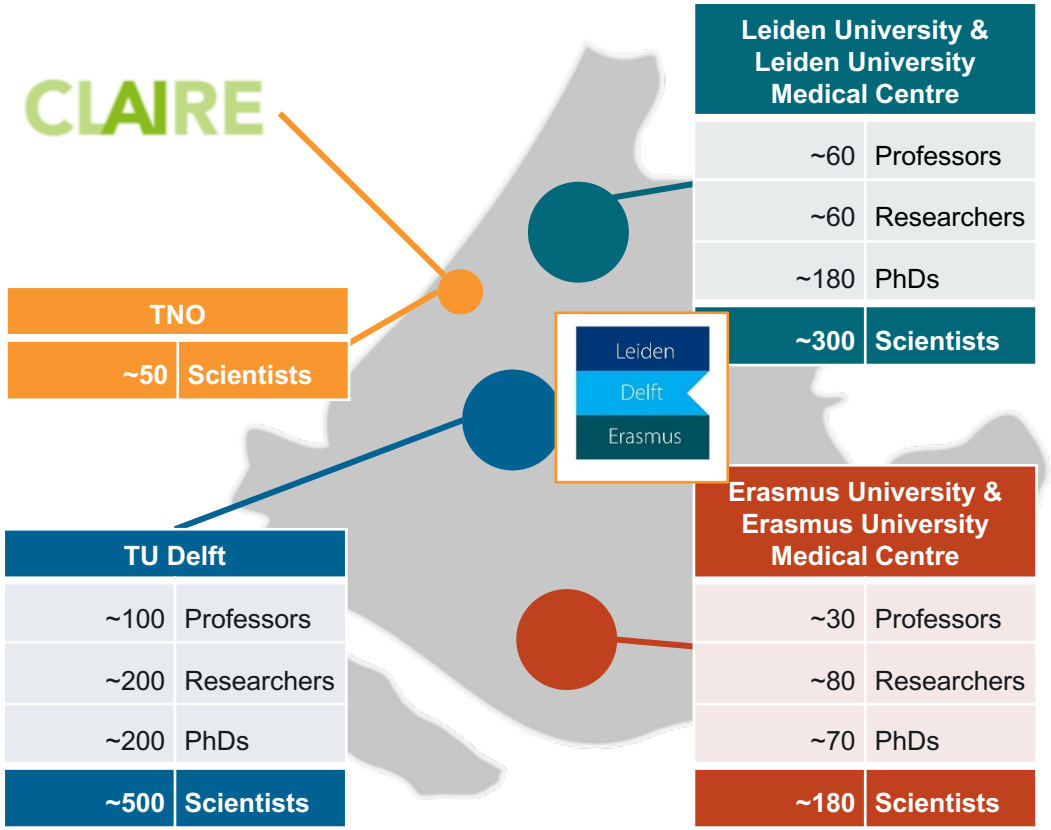
[1] Microsoft & EY (2019), Artificial Intelligence in Europe - Outlook for 2019 and Beyond.

~1.000 researchers active in AI-research

The Netherlands has more than 100 research groups that are related to AI and Data Science, of which ~20 are located in Zuid-Holland.

In Zuid-Holland, **~1.000 researchers are active in AI-**related research. **28 of the top 100 Dutch researchers** with the highest impact, are currently based at its three universities (Leiden-Delft-Erasmus alliance).[2]

- TNO, The Netherlands Organisation for **applied scientific research** has a location in The Hague focussing on AI and Data Science.
- Research in Zuid-Holland has both a focus on the **technical aspects** of AI (TU Delft, Leiden University) as well as a focus on **applications and societal frameworks and implications** at Erasmus University and TNO. This differentiates Zuid-Holland from the more fundamental AI-research that is performed elsewhere in The Netherlands.
- The Hague houses the **headquarters** of the Confederation of Laboratories for Artificial Intelligence Research in Europe (**CLAIRE**), an international network of scientists and industry researchers across Europe. As of 2020, the network is backed by **335 research groups** from 34 countries.



[1] These are researchers who have contributed academic papers that were published at leading international academic conferences in the field of AI and Data Science, worldwide total is 22.400, see Mantha & Kiser (2019), Global AI Talent Report 2019, retrieved from https://jfgagne.ai/talent-2019/.
[2] Impact based on h-index (>40) from ICAI (2019), AI in Nederland/AI in Amsterdam. Retrieved from https://staff.fnwi.uva.nl/m.derijke/dutch-computer-scientists/

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LDE alliance is at the frontier of AI research and planning to grow

The Dutch Special Interest Group on Artificial Intelligence (SIGAI)[1] identifies seven different research topics of Artificial Intelligence which are considered frontiers for research and development and are strongly represented in the Netherlands (see Appendix)

The Leiden-Delft-Erasmus (LDE) universities, including their Medical Centers (MCs), exhibit academic excellence across these topics, with several research groups lead by professors who belong to the **international frontier of research** (h-index > 40).

The three universities in Zuid-Holland have established a joint programme, which takes AI as central research theme. Together with the medical centres, these universities will invest **1 B€ across 10 years for AI research**. At least **30 labs will drive technological development** in AI and applications in law, linguistics, ethics and philosophy, logistics, finance, energy, health and climate.[2]

Universiteit Leiden The Netherlands

TU Delft Delft University of Technology

Erasmus University Rotterdam

Technology focus of Zuid-Holland Research institutes in AI-related fields[1]

Research excellence | Leading position (h-index > 40)

	Autonomous agents & Robotics	Computer vision	Decision making	Information retrieval	Knowledge representation & reasoning	Machine learning	Natural Language Processing
TU Delft							
Leiden University & MC							
Erasmus University & MC							

[1] Team analysis: Technology focus areas of Dutch Universities based on SIGAI, 2018, The Dutch AI Manifesto, Special Interest Group on Artificial Intelligence & Dutch computer scientists (updated Nov. '19) via https://staff.fnwi.uva.nl/m.derijke/dutch-computer-scientists/

2 NRC (2020), Vergaande samenwerking tussen TU Delft en Erasmus Universiteit en ziekenhuis, 10 januari 2020

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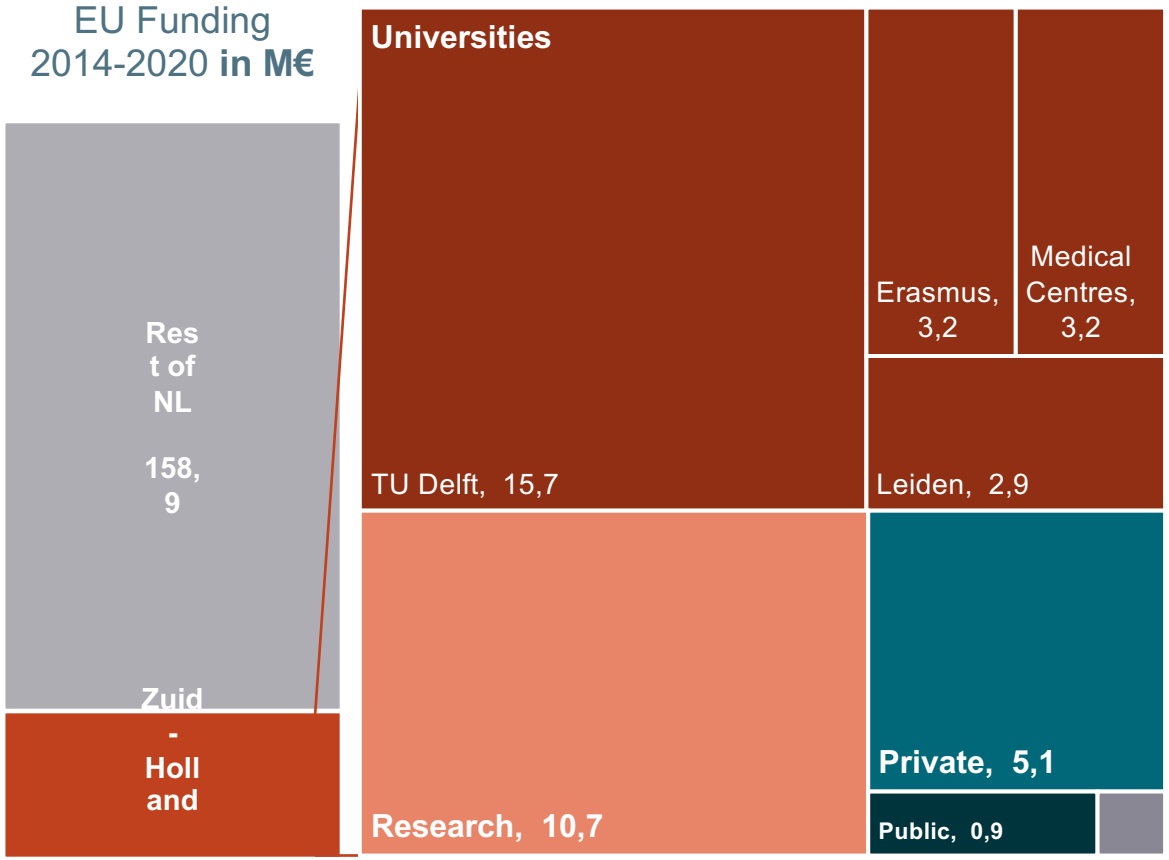
Zuid-Holland well positioned for opportunity of increased EU funding

Under the Horizon 2020 programme, an estimated 2,9 B€ in research funding was allocated to **AI technology related research**, of which 7% (almost 200 M€) was acquired by Dutch Organisations.[1]

- Organisations in Zuid-Holland take in **20% of Dutch EC funding** awarded to The Netherlands in AI-related projects. In total, **43 organisations** (22% of total) in Zuid-Holland received funding through **80 projects**.
- Together, the projects these organisations carry out connect ~1.300 organisations throughout Europe, of which 34% are private companies.
- The majority of funding is awarded to universities and (applied) research institutes such as TNO. Private organisations receive less funding but count for 50% of the recipients.

The EU provides **new funding opportunities** now and from 2021 to 2027.

- An additional investment boost within Horizon 2020 provides **1,5 B€** for Research and Innovation between 2018 and the end of 2020.
- After 2020 the EU will invest **1 B€ a year** through Horizon Europe and Digital Europe programmes. Within Digital Europe there is 2,5 B€ total specifically for AI.[2] In total, the EU aims to attract **20 B€ of investments a year** in AI from 2021 to 2027.
- With a leading network position in current European research, Zuid-Holland has an opportunity to expand research and innovation actions with support of the EU.



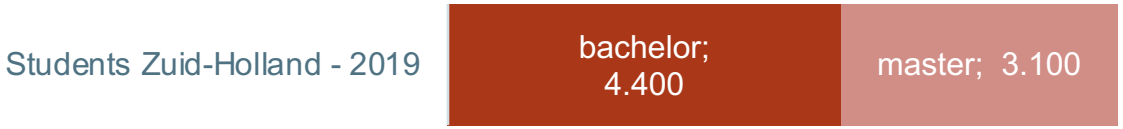
[1] CORDIS (2020), EU research results, retrieved from Eurostat, December 2019. For selection of projects, see Appendix.
[2] European Commission (2019), Artificial Intelligence for Europe & European Commission (2019), Digital Europe Programme.

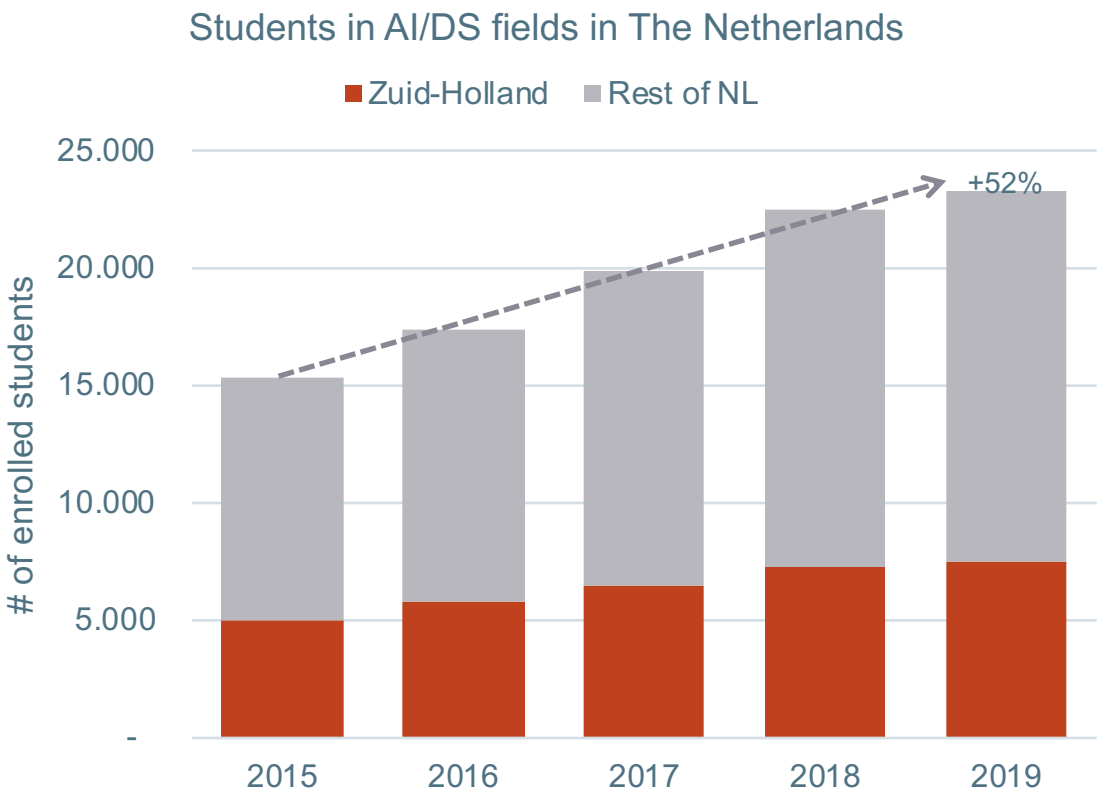
Innovation Quarter Birch

Popularity of AI studies is increasing rapidly, providing new AI talent

AI, Data Science and related studies are increasingly popular amongst students.[1] Due to new programs in AI and data science, growth is three times as fast in AI focused programmes (22% compound annual growth rate) as in related fields.[2] Of Dutch student population in 2019, **32% studied in Zuid-Holland** in 2018.

- Universities in Zuid-Holland **do not yet offer dedicated AI programmes** for students. However, there are AI specialisation tracks within computer science at both Leiden University (UL) and Delft University of Technology (TU Delft). UL also offers a minor data science. Erasmus University Rotterdam offers several master programs that integrate data science and machine learning in multiple disciplines and several post-academic data science tracks for professionals.[3]
- Largest and fastest growing programmes in Zuid-Holland are the **Computer Science & Engineering** bachelor (1.400 students, 16% annual growth) and the **Computer Science** master (780 students, 13% annual growth). These are the largest computer science programmes in The Netherlands.
- The ambition of the **Leiden-Delft-Erasmus alliance** is that **soon every student will come into contact with AI education** within their studies. These universities aim to reach **85.000 students in the next 10 years**[4].





[1] AI related education = bachelor and master tracks in AI and in fields that offer data science and AI specialisation, see Appendix.
[2] Based on DUO Open Data.
[3] See for example options in Leiden , Delft and Erasmus
[4] NRC (2020), Vergaande samenwerking tussen TU Delft en Erasmus Universiteit en ziekenhuis, 10 januari 2020

Innovation Quarter Birch

Strain on Dutch AI talent due to limited capacity and brain drain

The Dutch talent ecosystem is under increasing strain.

- The lack of resources at universities to manage the increasing number of students and grow the number of qualified education staff is problematic. As a consequence, many Dutch universities have instituted **student limits** in AI related bachelor programmes and the number of new students stagnates. Number in **red** signify a downward trend due to student limits.
- Master tracks also need to work with student limits. They use selection procedures to keep the number of students within carrying capacity of the universities. A good example is the master in Business Information Management (BIM) of Erasmus University Rotterdam, where a capacity limit of 250 students had to be set.
- Graduated **talent often leaves the Netherlands** to work elsewhere. Out of a sample of 210 PhDs trained in the Netherlands, 80 have since graduation accepted positions in other countries, mostly at Big Tech in the US.[2]

In the news:

- **"Student numbers grow faster than universities can handle.** (…) Universities cannot simply expand their facilities and the number of teachers when there is an increased interest. (…) The knowledge that is necessary to teach AI is very specific and there are not enough teachers with that knowledge."[3]
- "The Netherlands suffers brain drain in Artificial Intelligence."[4]

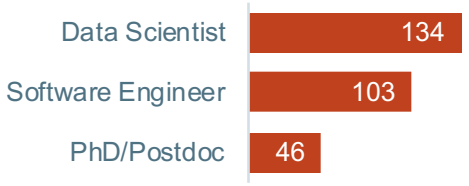
University[1]	Programme	Capacity limit 2020	New students 2018	New students 2019
University of Amsterdam	B Artificial Intelligence	*200 (since 2018)*	92	**69**
University of Groningen	B Artificial Intelligence	*150 (since 2019)*	149	**108**
Radboud University	B Artificial Intelligence	*185 (since 2018)*	123	**145**
Utrecht University	B Artificial Intelligence	*150 (since 2019)*	169	**89**
TU Delft	B Computer Science & Engineering	*500 (since 2019)*	704	**424**
TU Eindhoven	B Technical Informatics	*400 (since 2018)*	180	**219**
Leiden University	B Informatics	*No limit*	84	**124**

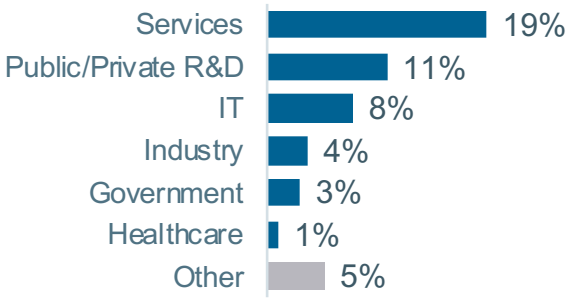
[1] Overview of programmes with limits, not exhaustive. Studiekeuze123 (2019). Overzicht van opleidingen met een numerus fixus in studiejaar 2020-2021.
[2] Mantha & Kiser (2019), Global AI Talent Report 2019, retrieved from https://jfgagne.ai/talent-2019/
[3] NOS (2018). Actieplan nodig voor populaire computertechnische studies. July 16, 2018.
[4] NRC (2018), Nederland kampt met brain drain in artificiële intelligentie. August 27, 2018

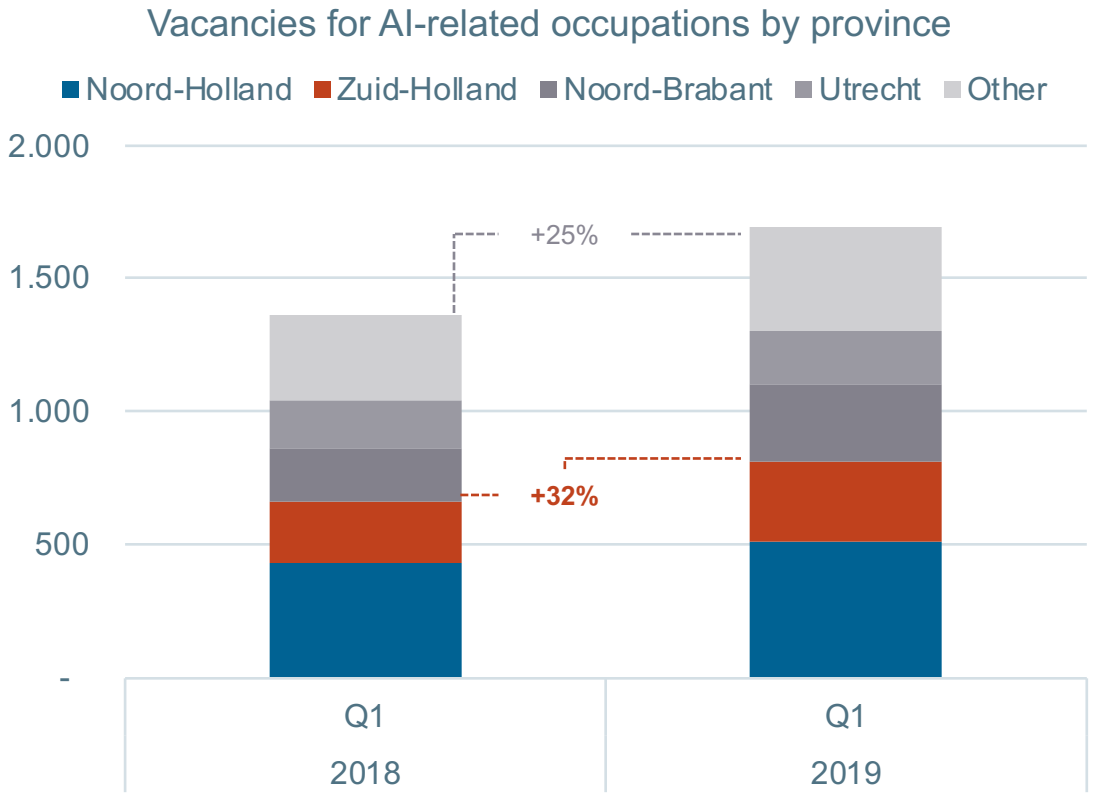
Zuid-Holland is a leading region in demand of AI skills, supply falls behind

Zuid-Holland has seen a steadily growing demand for AI-skills. The number of vacancies between Q1 2018 and Q1 2019 increased with 32%.[1]

- The **top 3 job listings** in Zuid-Holland are for 'Data scientists', '(Software) Engineers' and academic positions such as PhD and Postdoc positions.
- Vacancies for AI-related skills concentrate in Amsterdam, Eindhoven and the Rotterdam – The Hague region. The cities of Zuid-Holland are the **second most concentrated region** for demand in AI-related jobs
- Considering the brain drain and the strain on new students, there will be **increased tension to fulfil demand**, especially in senior positions.
- In the long run, AI will not only impact demand for jobs with a higher education background but also **influence the skillsets** needed for lower end jobs. This leads to both disappearance of old jobs and creation of new jobs.

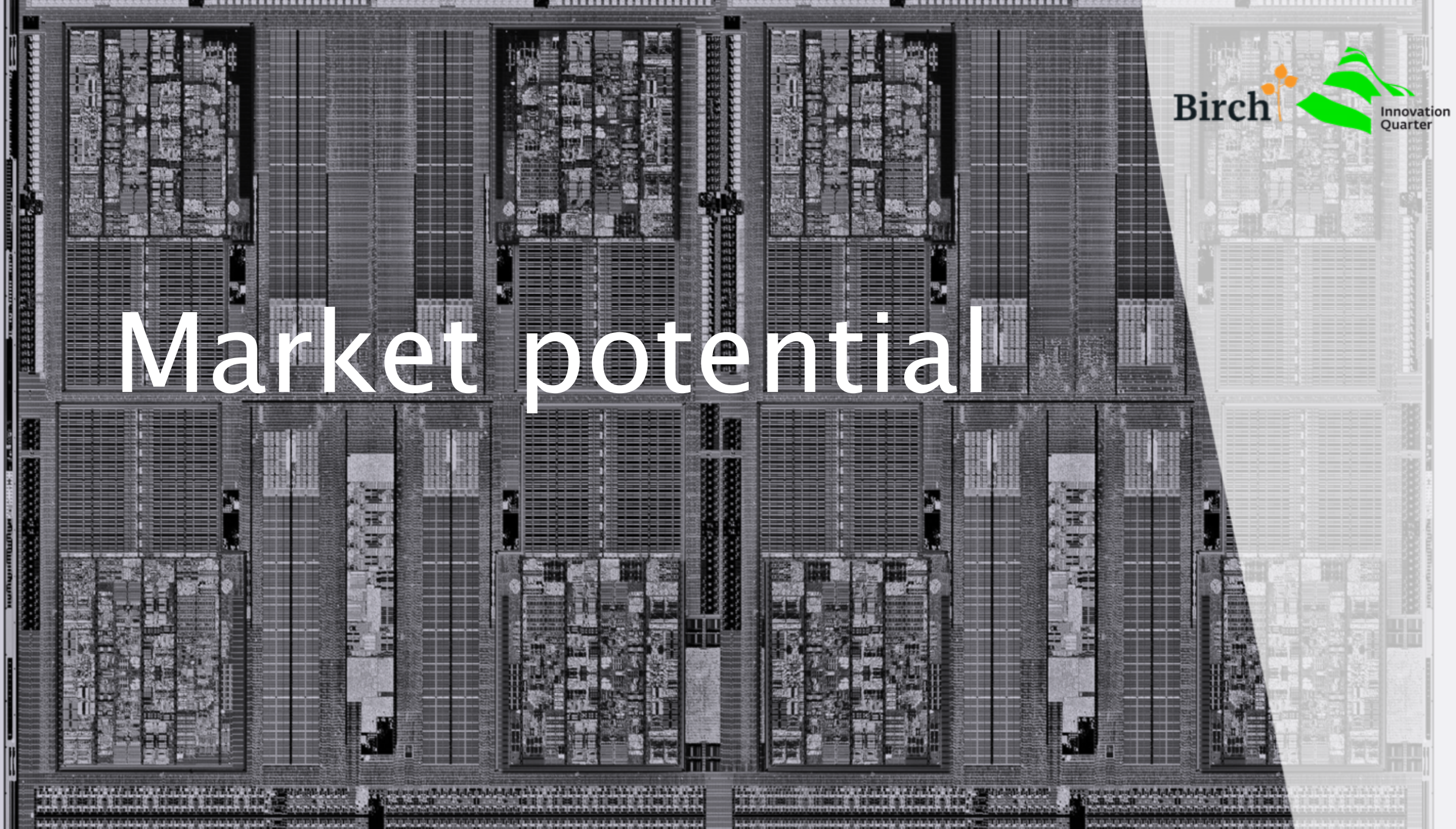






[1] Based on text analysis performed on a dataset of selected IT-vacancies. On a national level 5.909 vacancies in 2018 and 1.611 in Q1 of 2019 were recognised as inquiring for AI-related skills. Of the total number of vacancies 1.342 (17,7%) were from an organisation based in Zuid-Holland. See Appendix.
[2] The majority of vacancies is published by intermediary organisations (recruitment and staffing agencies) and thus industry cannot be determined.

Market potential



Birch Innovation Quarter

Marktet potential – main conclusions

Effective, safe and transparant use of data is a major challenge

Business Goals & Technologies

- Across all industries, the main business goal for AI technology is **providing forecasts, predictions and support on (future) decisions**. The second most relevant goal is **pattern and anomaly detection.**
- To fulfil these goals, **machine learning** and **computer vision** are the most demanded technology.
- AI technologies open up new possibilities in using already existing data and by combining these with data from external sources/

Business cases

- In highly automated industries, such as Manufacturing and Agri & Food, AI business cases revolve mainly around **optimizing already existing processes.** AI improves efficiency or reduces downtimes of business lines.
- In other industries AI technologies are expected to have more disruptive effects by **automating existing tasks and opening up new business lines**.

Regional Impact

- Across selected industries, AI can account for **~3 B€ in added value** in the selected key industries in Zuid-Holland and can **influence the jobs of ~100.000 people**.
- Largest immediate impact can be achieved in **optimising processes in existing large industries**. In smaller industries potential in the future is much higher and more uncertain.
- In multiple industries business cases for AI are strongly mission-driven: **working towards public good, such as** a safe, sustainable and healthy society.

Bottlenecks

- The major challenge across all industries is **the effective, safe and transparent use of data**. Most organisations do not yet have the knowledge and/or infrastructure to save and process the needed data.
- **Investments in staff and infrastructure** are not yet up to speed.
- There is **relatively low awareness** of the benefits of AI technologies on business and how these should be implemented.
- Investment costs in some industries do not yet outweigh (**often uncertain) gains**.

Innovation Quarter Birch

Market potential – Added value

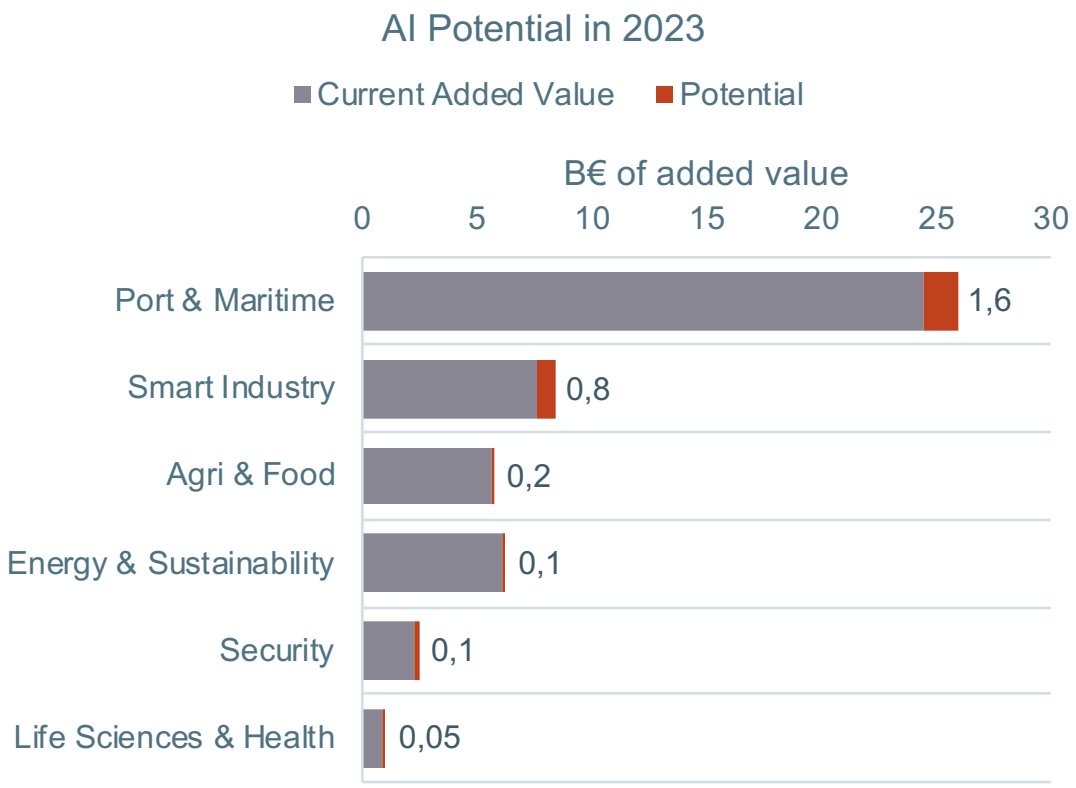
Key industries could generate ~3 B€ in added value by 2023

In this report we look at **six key industries** (see graph), which represent a **third of the economy in terms of added value in Zuid-Holland**. These industries are also all selected as priority sectors of the NL AI Coalition.

The potential economic effect is calculated based on international estimates. These assessments do not reflect regional context but provide an estimate of the size of the impact. Hence, these numbers are not forecasts but should be interpreted as a directional perspective.[1,2]

In total, AI potentially generates ~3 B€ in added value for Zuid-Holland over the next 3 years. At his medium long-term, the **most expected added value is ascribed to the Port & Maritime industry** due to its size and importance for the regional economy of Zuid-Holland. Relatively, the **highest economic impact of AI is expected in Manufacturing.**

Depending on our used industry delineation the potential will vary. For instance, Life Sciences & Health is defined as a small high-tech industry aiming to develop solutions for healthcare. Therefore, the bulk of healthcare (such as hospitals and healthcare at home) is not taken into account. However, it is important to note that AI has the potential to fundamentally change healthcare.



[1] Analysis based on: Erasmus Centre for Business Innovation (2018), Economische Bijdrage van de Speerpuntsectoren van Zuid-Holland. Rotterdam & McKinsey Global Institute (2018), Notes from the AI Frontier – Insights from hundreds of use cases.
2 The developments of the 'corona crisis' have not been taken into account, since our research has been done at an earlier stage

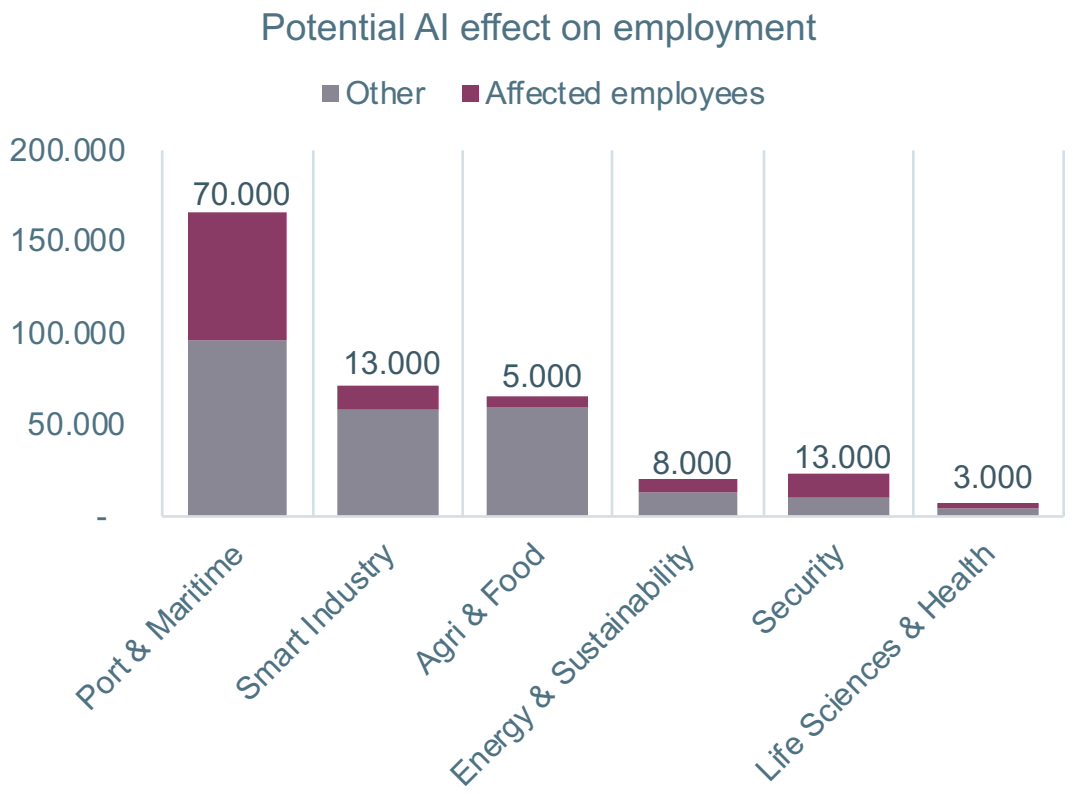
Market potential – Influence on jobs

AI could influence more than 100k jobs in the next three years

Jobs in the key industries represent a quarter of the labour market in Zuid-Holland. For the effect of AI on the labour market in these key industries, international estimates are used to extrapolate the impact for the industries of Zuid-Holland.

By 2023, it is estimated that AI could have had an effect on more than 100.000 jobs. AI will have the **largest absolute effect on employment** in the **Port & Maritime industry,** AI will have an influence on 70.000 of the 166.000 existing jobs (42%).
The **relative effect is highest** in the **Security industry,** where more than half of the existing jobs will be affected in one way or another by AI.

These numbers are not forecasts of number of jobs created or lost due to technological advancements, but rather estimates on how many jobs will be influenced by AI. This can be in the form of process-innovations such as automation, changes in the skills required in existing jobs or the creation of new positions to work with AI technologies.[1,2]



[1] Analysis based on: PWC (2017), Sizing the prize – What's the real value of AI for your business and how can you capitalise?
AI influence for all industries from: McKinsey Global Institute (2018), Notes from the AI Frontier – Insights from hundreds of use cases.
[2] The developments of the 'corona crisis' have not been taken into account, since our research has been done at an earlier stage

Market potential – Applications by phase of development

Industry focus and level of maturity of AI applications in Zuid-Holland[1]

	Security	Agri & Food	Life Science & Health	Energy & Sustainability	Manufacturing	Port & Maritime
Discovery			Personalized medicine, drug discovery and drug manufacturing			
Development	Cybersecurity threat recognition			Smart grids and forecasting of energy demand and supply	Connected production lines	Autonomous shipping
Demonstration	Experimentation with cybersecurity attacks	Anomaly detection in crops, selective breeding			Robotics, production line and quality control improvement	Predictive planning for logistics optimisation
Deployment	Basic cybersecurity applications	Harvest prediction and planning	Detection of diseases and medical diagnosis	Maintenance prediction of grids and equipment		Port terminal automation

[1] Team analysis based on expert interviews and desk research, not exhaustive.

Innovation Quarter Birch

Market potential: Port & Maritime

The Port & Maritime industrial complex in Rotterdam is a main driver of the economy of Zuid-Holland which provides employment to 166.000 people and 24,4 B€ added value to the region.

Business cases for AI: Several AI systems may have a high sector-wide impact. First, AI can provide new ways for automating terminals and vessels, such as unmanned and remote-controlled terminals, cranes and cargo ships. In addition, AI systems can predict vessel movements based on historical data and weather conditions. This would increase efficiency in planning resources and maintenance.
AI goals: Applications are required to make autonomous logistical decisions based on predictions which include environmental factors. In more advanced use cases, autonomous goal-driven systems will be used to navigate and dock ships. To conclude, AI will increasingly monitor and predict machine failure with pattern analysis.
AI technologies: Machine learning based on sensor data, robotic process automation and natural language processing. This in turn requires extensive data collection and transmission.
Industry Predictions: Global predictions are that 42% of logistics companies are ready to adopt AI (to a certain level) in 0-3 years[1] and that AI may influence up to 6% of revenue.[2] Most opportunities are in improving existing optimisation strategies for travel time, fuel use and customs inspection. Further down the line, automation will have larger impact. Terminals can be almost fully automated and remotely operated, using automated cranes to unload ships and Automated Ground Vehicles (AGV) to transport containers.[3] Autonomous ships interacting with these systems provide even more opportunities.

Technologies

Autonomous Agents & Robotics	Computer Vision	Decision Making	Information Retrieval	Knowledge Representation & Reasoning	Machine Learning	Natural Language Processing

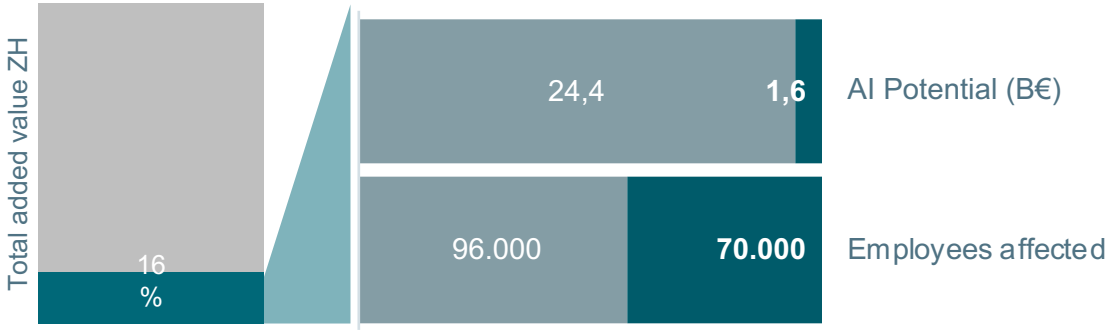
[1] AI adoption percentages for all industries from: PWC (2017), Sizing the prize – What's the real value of AI for your business and how can you capitalise?
[2] AI influence for all industries from: McKinsey Global Institute (2018), Notes from the AI Frontier – Insights from hundreds of use cases.
3 Port of Rotterdam (2019). The robot is coming.

Market potential: Port & Maritime

Readiness in the region
The Port of Rotterdam has taken steps in data science with IBM, Cisco and ESRI to build a 'digital twin' of the harbour. This provides both data on the physical layout of the waterways and environmental (weather) conditions. For this to have impact, shipping companies, terminals and port authority all require access to this data to combine it with data gathered from their own machinery.

Several terminals are almost fully automated, with both automated cranes and AGVs. Further adoption of these technologies could optimise cargo flow and efficiency but will have severe impact on the available jobs in the port.

There have been several successful tests with autonomous sailing within port boundaries by Captain AI. The Dutch Joint Industry Project Autonomous Shipping, a consortium of 17 organisations including TNO and TU Delft, is testing autonomous vessels on the North Sea.



Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
++	--	++	++	--	0
Proven technology for logistics	Complexity prevents data sharing	Small intervention has large returns	AI useful across value chain	Mistrust from traditional employees	

Opportunities
All the required technology is available and **ready for implementation** in a port setting. The required investments in AI will be high (especially for new equipment and talent) but since operators deal in such large volumes even **small improvements in efficiency can add significant value**. There is an opportunity for Zuid-Holland here through several actions:
1) Set up **pilot programs** with multiple stakeholders in the port environment, focusing on **data sharing support**
2) Help in increasing awareness and knowledge exchange to **build AI expertise** in maritime- and port companies
3) Build trust in AI technology and provide viable alternatives for workers. Employees are **not yet accepting of the use of AI technology**, distrusting potential privacy issues and doubting if it will help them do a better job.

Market potential: Manufacturing

Manufacturing industry in Zuid-Holland provides employment to 72.000 people and 7,6 B€ added value to the region. It consists mostly of high-tech manufacturing and specialised suppliers of industrial machinery.

Business cases for AI: Leveraging AI in optimizing the manufacturing process. Intelligent and self-learning monitoring can make predictions based on existing live data, reducing delays and subsequent costs. It decreases the possibility of deviations from product specifications. In addition, AI opens possibilities for the use of generative design (i.e. a program generating design alternatives based on certain inputs) and further automation via new ways to program robots.
AI goals: Recognising and assessing physical objects in a production process, using process data to detect and predict outcomes in a production line and reacting automatically to adapt production inputs.
AI technologies: These goals are met with machine learning models that use sensory input data (often generated by computer vision) to predict outcomes, make decisions and control the robots and machines that manipulate the production process.
Industry Predictions: AI in manufacturing is considered more of an evolution than a revolution: techniques like automation, robotics and complex analytics have been used for years. AI adds more efficiency and flexibility to these processes. Long-term, AI and datafication may lead to a shift from single machine systems to factory ecosystems, which reduces costs in designing and manufacturing new (customizable) products. Globally, predictions are that 14% of technological companies are ready to adopt AI in 0-3 years and AI can influence up to 10% of revenue.

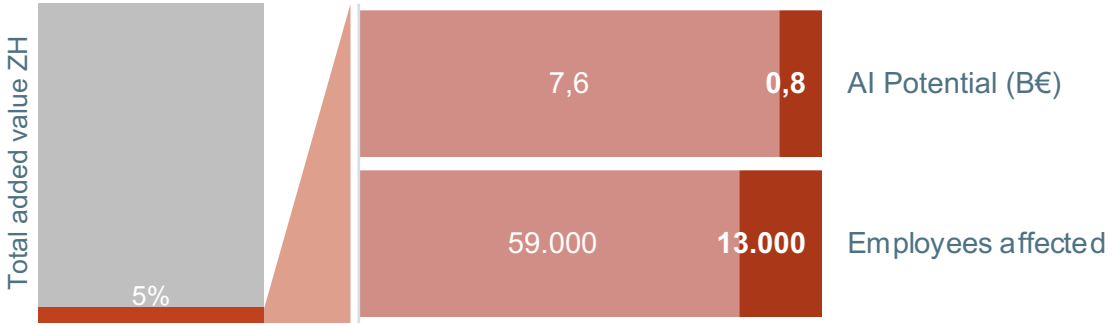
Technologies

Autonomous Agents & Robotics	Computer Vision	Decision Making	Information Retrieval	Knowledge Representation & Reasoning	Machine Learning	Natural Language Processing

Market potential: Manufacturing

Readiness in the region
In The Netherlands, 19% of companies in knowledge-intensive manufacturing is working with big data analytics, one of the requirements to adopt AI solutions.[1] Zuid-Holland has several field-labs (supported by Smart Industry Hub SMITZH), which support organisations in applying robotics and big data applications. For instance, several equipment manufacturers invest heavily in R&D by building data frameworks and products based on AI models to increase efficiency. Most of these investments go into AI talent, rather than physical infrastructure.

Robovalley is already supporting AI knowledge exchange through training and network events on robotics. It also offers test facilities (Robohouse in Delft) and programmes for innovation in cognitive robots and applying machine learning.



Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
++	-	-	+	++	+
Efficiency & automation	Data structure and exchange	High upfront investment	Gains in efficiency but lower priority	Automation is business as usual	No obstructing industry policy

Opportunities:
The use of AI-technology is considered a logical next step which will lead to increased efficiency, safety and flexibility. The first applications are currently being used. To succeed, Zuid-Holland may focus on three opportunities:

1) **Remove bottlenecks** in effective use of data and connectivity within manufacturers and between supply chain partners.
2) Improve potential demand by finding a **wider range of applications** for AI technology than in efficiency and automation, such as in product development.
3) Universities have a **strong knowledge base** in robotics and automation. They could more frequently utilize this expertise in real world situations. With a focus on finding, testing and scaling useful industry-wide AI-applications.

[1] RaboResearch (2019), AI, gaat het wel goed?

Market potential: Agri & Food

The Netherlands is one of the largest exporters worldwide of Agri & Food products and knowledge. Within this industry, the national strength of Horticulture is predominantly based in Zuid-Holland. It adds around 5,6 B€ of value to the regional economy, employing 65.000 people.

Business case for AI: Globally, the demand for resource intensive foods is growing exponentially. This puts pressure on the Agri & Food industry to increase efficiency. In horticulture, AI is able to process genomics data and support in predictive breeding. Algorithms can make predictions to optimize cross-breeding of seeds and plants. In addition, detection of anomalies in seeds and crops can reduce waste. Also, there are significant potential gains in harvest prediction and planning: leading to optimal harvesting moments and increased production efficiency.
AI goals: A major goal is to provide predictive analytics based on a wide range of data points ranging from weather conditions, (glass house) temperature and soil condition. In addition, technologies should be able to spot anomalies in plants and seeds.
AI technologies: Machine learning on the multiple data sources and crop outcomes as well as computer vision technology to recognize seed and crop status.
Industry Predictions*:* In general, Agri & Food is a data-rich industry in which a number of repetitive tasks are performed to achieve an optimal production cycle. This makes it a good breeding ground for AI. Nevertheless, the industry has a relatively low AI maturity prediction. It is expected that 8% of organisations in the industry will adopt AI technologies within 3 years. In Zuid-Holland it is expected that AI technologies can account for 0,2B€ in added value.

Technologies

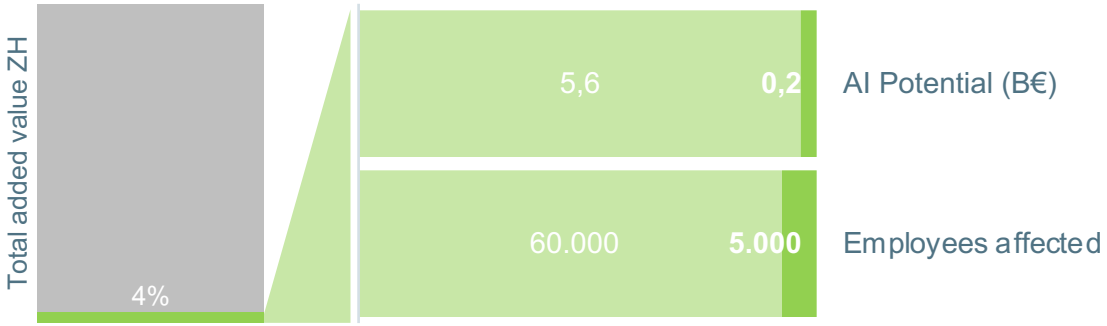
Autonomous Agents & Robotics	Computer Vision	Decision Making	Information Retrieval	Knowledge Representation & Reasoning	Machine Learning	Natural Language Processing

Market potential: Agri & Food

Readiness in the region
In Zuid-Holland, one of the biggest challenges for the industry is finding AI & Data Science talent with an interest in Horticulture.

In addition there are (IT) infrastructural challenges in applying computer vision and machine learning technologies in glass-houses. Currently, there is regional potential in initiating R&D coalitions and innovation projects. This will strengthen the regional horticulture cluster and will make it more future proof.

The region houses the World Horti Center, an innovation hub for horticulture companies, which provides incubation services, knowledge transfer, training and network events. The recent RoboCrops initiative is a starting point for new knowledge in the industry on AI and robotics.



Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
+	-	-	+	++	0
Optimization challenges fit for AI	Low data maturity and knowledge exchange	Returns in increased efficiency	Increased demand due to worldwide challenges	Highly automated industry	

Opportunities
As the horticulture cluster in Zuid-Holland is one of the largest in the world, being at the forefront of innovations opens possibilities in **exporting new technologies** worldwide.

The horticulture cluster faces tough challenges with regards to **human capital (shortage of staff) sustainability and circularity**. AI technologies can provide opportunities to tackle these challenges.

There are also opportunities in **increased collaboration:**
1) Currently, newly acquired data analysts do not have peers to **exchange knowledge** and experiences. This halts the implementation of innovative technologies.
2) More **cross-over collaboration** with other industries could be beneficial.

Market potential: Energy & Sustainability

Zuid-Holland has one of the largest CO_2 emission profiles of Europe, which is mostly due to the large industrial and port & maritime complex which uses ~30% of energy demand in the region. The Energy & Sustainability sector in Zuid-Holland relates to all organisations in (sustainable) energy sources, sustainable mobility and energy infrastructure. It has approx. 21.000 employees in Zuid-Holland and adds a total value of 6,2 B€ to the economy.

Business case for AI: Data Science and Machine Learning algorithms can reduce maintenance costs of both energy grids and equipment by failure probability modelling. One of the big challenges of the industry is forecasting energy grid demand and optimizing feed-in from sustainable energy sources. AI technologies can predict demand and make optimized pricing recommendations.
AI goals: Algorithms are used for predicting the influence of weather conditions, asset values and energy usage (among others) on the power grid. This provides useful insights for energy demand side management and performance management to optimize energy flows between providers and consumers.
AI technologies: Machine learning to process and analyse data from a wide range of sources. This includes detecting patterns in energy supply and demand, as well as decision making technology to balance the grid.
Industry Predictions: Globally, 39% of the energy sector is expected to adopt AI technologies within 3 years. The collection of data is currently taking a surge with smart meter adoption. Now for gas and electricity, soon also for heat. This provides new insights into usage patterns.

Technologies

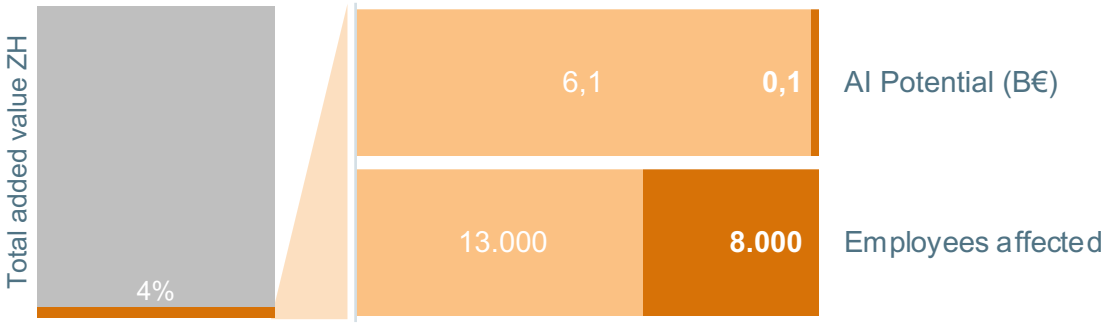
Autonomous Agents & Robotics	Computer Vision	**Decision Making**	Information Retrieval	Knowledge Representation & Reasoning	**Machine Learning**	Natural Language Processing

Market potential: Energy & Sustainability

Readiness in the region
The Province of Zuid-Holland has set drastic goals to reduce energy usage in industry and to largely use sustainable energy sources in 2050. Hence, innovations in the Energy & Stainability industry are both highly anticipated and stimulated.

Adoption of technologies with regard to optimised grid management and the improvement of renewable energy supplies are on the agenda. To start implementing this effectively, investments in monitoring equipment, smart grids and IT infrastructure are needed.

Corporates and operators, active in the industry affirm the opportunity to work with innovative startups and scale-ups that supply AI technologies directed at the Energy & Sustainability industry. However, the IT infrastructure to make effective use of relevant data streams is often not in place to make use of these technologies.



Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
++	-	++	-	+	0
Data is suitable for AI applications	Investment in meters and monitoring needed	High sustainability benefits	Low awareness	'Smart' energy is on the agenda	

Opportunities
Effective management of (smart) energy grids can result in massive gains in sustainability, efficiency and reliability. An important aspect in achieving this is **creating awareness at organisations on the demand side.** They benefit from data driven usage of energy.

Short-term, **providing information** to medium-large organisations on how they can **optimize their energy usage** by using data, can result in less peak time demand of the grid.

To progress with 'smart energy', a regional **consortium of relevant organisations** is needed consisting of grid operators, energy suppliers, large industrial companies/users and innovators.

Market potential: Security

Security in Zuid-Holland provides employment to 23.000 people and 2,3 B€ added value to the region. Zuid-Holland has strengths in both cybersecurity and public safety.

Business cases in security: Within Security there are two main subsectors which have different business cases for AI; cybersecurity and public safety. For cybersecurity, AI supports analysts through improving detection of threats and increasing efficiency (by filtering out false positives). For public safety, AI is supportive in (among others) scenario planning and optimisation of crisis response patterns.
AI goals: Improving security requires handling large datasets, such as dealing with server requests, spotting information breaches, analysing sensor data or camera images). AI recognises patterns and anomalies and uses these patterns to make predictions about future threats.
AI technologies: Machine Learning regarding previous threats and detecting future ones. Decision making for improved response to threats and attacks, which requires knowledge representation to assist analysts.
Industry Predictions: Globally, predictions are that 57% of security companies are ready to adopt AI in 0-3 years and AI can influence up to 6% of revenue.[1] Based on worldwide trends, the market for cybersecurity is expected to double in the next five years and 87% of cybersecurity companies report using AI as part of their products. An important driver behind this development, is the fact that AI is used by both attackers and defenders. Deep learning will play a role in these tools, but AI cannot fully automate cybersecurity: humans in the loop will remain required.[1]

Technologies

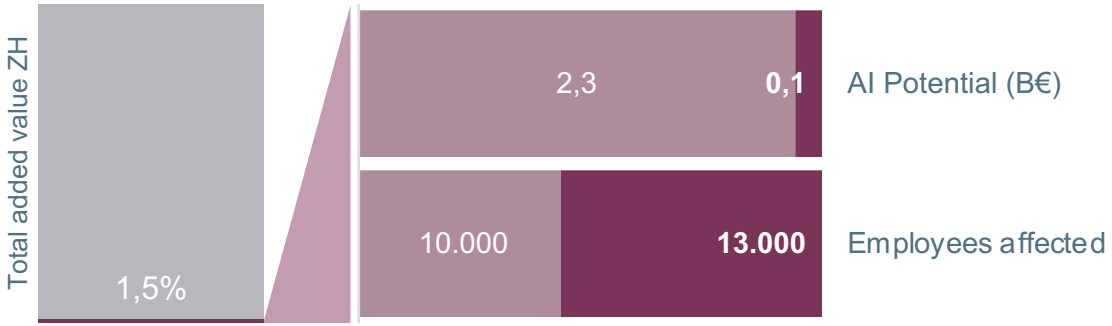
Autonomous Agents & Robotics	Computer Vision	Decision Making	Information Retrieval	Knowledge Representation & Reasoning	Machine Learning	Natural Language Processing

[1] PWC (2018), 2018 AI predictions – 8 insights to shape business strategy

Market potential: Security

Readiness in the region
The Dutch security cluster is clustered mainly around The Hague and Delft. The region has the capabilities to organise innovation programmes and deploy new innovations at scale in both private companies and with the public sector. The region has a strong knowledge base. TU Delft, TNO and leading companies in the network of The Hague Security Delta have dedicated research and development programmes for artificial intelligence in (cyber)security operations. Cybersecurity also plays an important role in the digitization of the port industrial complex around Rotterdam.

The city of The Hague houses multiple national and international public organisations that deal with cybersecurity and data science (NCIA, EC3 & NCSC). Furthermore, the region houses the headquarters of several international telecom providers. These government entities and large corporations act as launching customer and investors in new cybersecurity solutions.



Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
-	-	+	++	--	-
Data not all suitable for machine learning	Not all processes should be automated	Prevention of (economic) damage	Every company needs security	'Black boxes' and ethical problems	Policy progress is behind on reality

Opportunities
In cybersecurity applications, data quality is key. Without good quality data, algorithms are unable to effectively recognise patterns. Of the anomalies detected, only a tiny fraction is truly malicious, **leading to bias** and false results. This means human intelligence is vital to judge incoming threats. There is an opportunity for **more research and development on cybersecurity. For example building public-private partnerships in the field of automated SOCs.**

There are several opportunities in Zuid-Holland that could use support:
1) More research into **explainable AI** (demystifying black boxes in use today) will be crucial for further adoption of AI measures for safety and security.
2) Lab environments are useful for **experimenting with AI-driven cyber security attacks (and responding these)**, involving multiple private partners and challenging them to share data.

Market potential: Life Sciences & Health

Life Sciences & Health (LSH) in Zuid-Holland provides employment to 8.000 people and 0,9 B€ added value to the region. This fast growing cluster consists of all high tech activities related to medical technology such as pharmacy, medical equipment and medical research. LSH is closely related to the larger Healthcare industry (200.000 people), which implements innovations developed within LSH.

Business case for AI: Data Science and AI technologies can be widely used in the Healthcare industry. Fore example to simplify, accelerate and improve diagnosis. In the (near) future it is expected that AI will play a prominent role in innovations regarding personalized medicine, drug development, and hospital operations.
AI goals: AI technologies should be able to support healthcare professionals in their work, both medical specialists as nurses. For breakthroughs in personalized medicine, algorithms should be able to cluster patients in certain risk categories based on existing and new patient data and profiles.
AI technologies: Computer vision keeps improving to recognise and assess anomalies in (medical) images. Several systems, driven by deep learning, already outperform humans in spotting diseases by analysing processed medical scans.[2] Machine learning can (a.o.) be used to make predictions and assess risks of patient groups through personalised records.
Industry Predictions: Globally, predictions are that 33% of medical companies are ready to adopt AI in 0-3 years and that AI can influence up to 6% of revenue. More than half of the healthcare providers in The Netherlands are implementing or are planning to implement AI technologies.[1]

Technologies

Autonomous Agents & Robotics	Computer Vision	Decision Making	Information Retrieval	Knowledge Representation & Reasoning	Machine Learning	Natural Language Processing

[1] HIMSS Analytics (2018). AI use in European Healthcare.
[2] McKinney, S.M., Sieniek, M., Godbole, V. et al (2020). International evaluation of an AI system for breast cancer screening. Nature 577, 89–94

Market potential: Life Sciences & Health

Readiness in the region
Zuid-Holland is a breeding ground to implement AI in Healthcare. Leiden Bio Science Park is the largest life sciences cluster in the Netherlands. Here, biotech companies are actively connected with researchers and healthcare providers. The regional LSH cluster is one of the largest in Europe. Leading companies, researchers and healthcare providers are strongly connected. Its international recognition is an asset to attract AI talent to the region.

With the Erasmus Medical Centre as frontrunner in computer vision research and several startups bringing technologies to the market, Zuid-Holland is also a hotspot for AI medical imaging processing technology.

Broadly, AI technologies for healthcare are rapidly developing. However, the accessibility of data is low: a lot of limiting factors due to concerns in **privacy, safety and reliability**. Hospitals and other healthcare providers are starting to develop methods to guarantee the privacy and safety of their patients.

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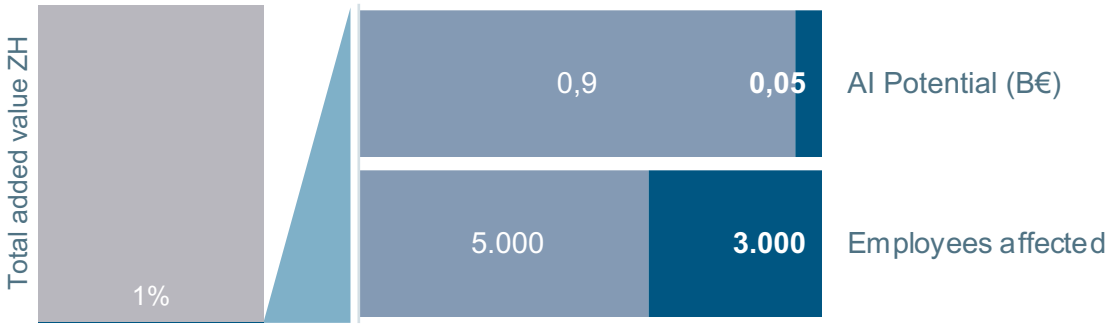


Technology		Industry & market			Policy
Technology fit	Industry capability	Expected (economic) returns	Potential demand	Legitimacy	Policy Framework
++	--	++	+	-	--
Technology supports daily activities	Data issues: privacy, security and reliability	Drastic cost reductions and societal benefits	AI useful across value chain	Replacing human tasks causes resistance	Difficulty in data sharing under GDPR

Opportunities
Accountability is an important issue in healthcare: the '**black box' nature of machine learning is challenging** as human lives are often directly affected by decisions influenced by these technologies. Action is needed to:

1) Remove barriers for **ethical and anonymous data-sharing** of patients.
2) Focus on **public value and explicability**.
3) **Make medical professionals more aware of AI opportunities, to increase acceptance.** When their work threatens to become (partly) replaced by AI, they not seldomly perceive it as threat. Important is to highlight benefits for professionals. Such as downscaling routine tasks, providing more time to use their high-level expertise.

Recommendations

Birch Innovation Quarter

Ambition of Zuid-Holland

Becoming a leading international region for mission-driven AI

Zuid-Holland has the research capacity, the startup ecosystem and the industry mass to become one of the main hubs for AI in The Netherlands and Europe. It should proliferate itself as **frontrunner in mission-driven AI**, referring to the potential of **making economic- and societal impact with AI in its leading industries**. This will need a focus on four core tenets of an AI-strategy:

- Strengthening and expanding the existing AI **knowledge base** that is the source of new opportunities for knowledge transfer
- Accelerating AI implementation through **new business cases** in existing industries through startups, public- private partnerships and intrapreneurship.
- Focussing on the digital transformation of multiple **world-renowned (Dutch) industries**, while embracing their related variety and enabling crossovers
- Putting **human capital** at the centre of development, by growing new talent from universities and retraining existing employees.

Using these principles, Zuid-Holland can create leverage through improving existing regional collaboration, starting new partnerships both within the region and with other Dutch Ecosystems dovetailing the National AI strategy. InnovationQuarter can play a pivotal role in these efforts, both in strengthening regional collaboration and in designing interventions that fit the organisation's supportive role in the ecosystem.

Supporting the regional AI ecosystem

Zuid-Holland's AI ecosystem could be supported by improving boundary conditions and increasing strengths. On the short and medium-term, InnovationQuarter and its regional stakeholders should **address three concrete challenges:**

1. Talent availability	•Leiden-Delft-Erasmus universities can increase AI efforts by working on a joint value proposition; aiming to increase AI capacity, build dedicated AI programs and develop other measures to prevent brain drain.
2. AI-readiness in industries	•SMEs, corporates and university research groups can improve the exchange of AI knowledge and implementation experiences. In addition, strengthening datafication programmes would help SME's to improve their AI-readiness. All efforts should be linked with national and international (European) initiatives.
3. Changing skills due to AI	•Key players of the Human Capital Agenda Zuid-Holland can take AI developments into consideration in skills deals and retraining efforts in line with human-centered AI principles.

Tackling these challenges will require **an effective regional AI coalition** with representatives from government, industries and knowledge institutes. This coalition will need the mandate to transform the current regional strengths into an **actionable regional plan** with a joint communication strategy.
The regional strength of Zuid-Holland is only significant with a national approach in an international context. Zuid-Holland industries will benefit from cross-regional collaboration (in for instance Life Sciences & Health with Amsterdam or HighTech Manufacturing with Eindhoven) and national coordination.

These challenges can be met with quantified goals. E.g.: for talent and changing skills, the region aims to educate 1.000 AI-specialists each year and give substantial AI training to 10.000 students. Similar goals can be set for reaching entrepreneurs, incubating and scaling AI startups and changing existing industries.

Interventions

InnovationQuarter can play a key role, especially in AI-readiness

As the regional economic development agency, InnovationQuarter can take several actions to enhance the innovation potential of the ecosystem, in collaboration with major corporations, SMEs, educational and research institutes and government organisations. Interventions to **improve AI-readiness,** can be made through the three key working areas of InnovationQuarter: innovation, investment and internationalisation.

Innovation

- Develop datafication/AI programmes and projects for key industries, including:
  - Port & Maritime: joint digitization and datafication program: involving port and maritime industry
  - Energy: deployment of smart energy technology by industry
  - Smart industry: enhance utilization of sensory input data and machine interactions
- Support SME networks for datafication and AI implementation practices
- Enhance community building for AI innovators

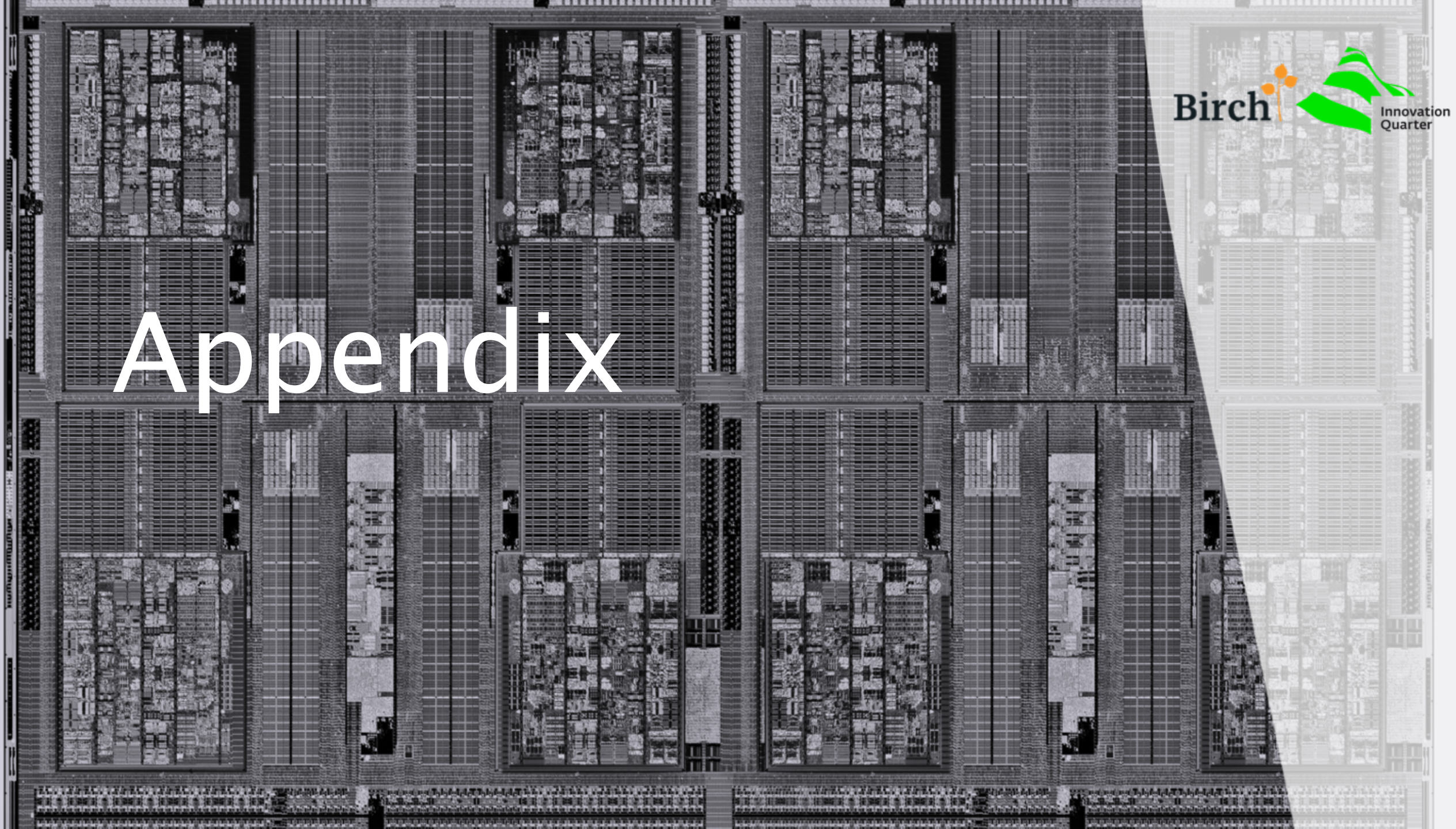
Investment

- Set up a knowledge transfer incentive fund for AI collaborations and pilots between universities and industry, open to both corporates and SMEs.
- Improve the network with private and public investors (Invest-NL, Techleap.nl, Venture Capitalists, Private Equity) to enable more structural scaleup funding.
- Focus part of funding on *implementation led* innovation within industries with low AI-readiness.
- Build accelerator programs for the startup-to-scale-up stage

Internationalisation

- Raise awareness of incoming funding opportunities by European Commission with public research institutes and private research efforts.
- Regional branding and communication as ’hub for mission-driven AI’ in international context and on trade missions.
- Scout relevant partners for R&D in AI, based on key industries and value chains.

Appendix



Appendix I - Frontiers of Artificial Intelligence

The frontier of AI is continually moving and expanding

AI is a constantly changing field, in which researchers are constantly discovering new ways to improve the performance of AI, either by developing new approaches to algorithms, or in tackling new problems with existing AI technologies.

The Dutch Special Interest Group on Artificial Intelligence (SIGAI)[1] identified seven different research topics of Artificial Intelligence which are considered frontiers for research and development and are strongly represented in the Netherlands. For each of these topics they have identified research challenges. Additionally, the researchers focus on AI that is responsible, socially aware and explicable.

Autonomous Agents & Robotics	• Developing autonomous computer systems acting in environments in order to achieve their design objectives, often interacting across system boundaries with other systems. • *Challenge is to improve robots' capabilities to perceive, manipulate and navigate their environment and interact with other agents in a coherent architecture.*
Computer Vision	• Obtaining a visual understanding of the world. • *Challenge is to design algorithms with better interpretation capabilities that require less supervision and work together with other techniques (from e.g. machine learning).*
Decision Making	• Planning and scheduling, heuristic search and optimization. • *Challenge is to design algorithms better capable of dealing uncertainty in (sequential) decisions (with multiple agents) and combine reasoning with machine learning.*
Information Retrieval	• Technology to connect people to information, e.g. search engines, recommender systems or conversational agents. • *Challenge is to better understand human input and optimise result generation.*
Knowledge Representation & Reasoning	• Representing information computationally, and processing information in order to solve complex reasoning tasks. • *Challenge is to integrate KR&R techniques with machine learning, and deal with more complex datasets.*
Machine Learning[2]	• Learning from data (using e.g. neural networks and/or statistical techniques). • *Challenge is to integrate pattern recognition with higher order knowledge, develop better reinforcement learning algorithms and make algorithms better classify uncertainty.*
Natural Language Processing	• Extracting information from spoken, written, and signed natural language, enabling human-machine communication and supporting human-human communication. • *Challenge is dealing with cultural diversity and achieve more natural generation of text and speech and technological language independence.*

[1] SIGAI, 2018, The Dutch AI Manifesto, Special Interest Group on Artificial Intelligence, The Netherlands. Autonomous Agents & Robotics

[2] Although Machine Learning is an 'umbrella' technology essential for the other frontiers, the SIGAI makes it a separate category to highlight progress that can be made within the design of machine learning, as opposed to its use in other technological fields.

Not all predictions and expectations about AI are realistic

Since most AI applications are still in a developmental phase, it is not always clear what AI will be and not be capable of in the future. This uncertainty sometimes leads to misconceptions. There are a few biases in popular use that should be taken into account with regards to innovation and market potential.[1]

- **Over- and underestimation**: We tend to overestimate the effect of AI in the short run and tend to underestimate in the long run. Most innovative technologies follow a process in which there are big promises upfront, followed by comparatively disappointing results.
- **Imagination**: We find it hard to imagine AI applications that do not exist yet. Imagining something that is not real (yet) almost feels like imagining magic. At the same time we should watch out for arguments about future applications of AI that are faith-based instead of based on scientific evidence.
- **Generalization**: We have the tendency to confuse performance of AI systems on a certain task with the competence to execute other tasks that could be expected from a person doing that one task. We generalize human competencies on AI systems. The same tendency occurs with umbrella concepts such as 'learning'. When we hear that machine 'learning' is making great progress, we use the mental model for the word 'learning' as we humans know it. This creates a misconception of what and how the system actually learns.
- **Speed**: New software versions are deployed frequently. This is possible because the marginal costs of deploying new code are low. However, deploying hardware has significant marginal costs. Capital costs keep hardware around for a longer time. That is why newly introduced AI systems will most likely not immediately trickle down into general operations.

It is helpful to keep in mind that these biases affect our understanding of new technologies. To prevent biases we keep our analyses evidence-based as much as possible.

Finally, the development of AI can be presented as the next inevitable technological revolution. Whilst true that advances in this field are rapid, it is important to remember that people and organisations guide these developments into good and bad usages of AI. To assume that every challenge can be met with AI solutions is to miss the nuances that surround this technology's capabilities. Questioning whether AI technology is appropriate for the challenge will provide for better decisions in the applications of AI in the future.

[1] Brooks (2017), The Seven Deadly Sins of AI Predictions. MIT Technology Review.
[2] Blauw (2019), Banking on AI to fix all our problems? Hate to disappoint you. The Correspondent.

Data selection start-ups and scaleups

DataFox: database with financial information of ±4,5 million companies

Filters
- Location: Netherlands
- Industry Keywords: Artificial Intelligence, Machine Learning, Natural Language Processing, NLP, Deep Learning, Data Science, Predictive Analytics

Download: 23-10-2019
Dataset DataFox: 316 companies

Dealroom: database with financial information of ±870.000 startups, scaleups, corporates and investors.

Filters
- All Locations: Netherlands
- HQ Locations: Netherlands
- Tags: Artificial intelligence, Machine learning, Natural language processing, Data analytics, Predictive analytics, Deep learning, Computer vision

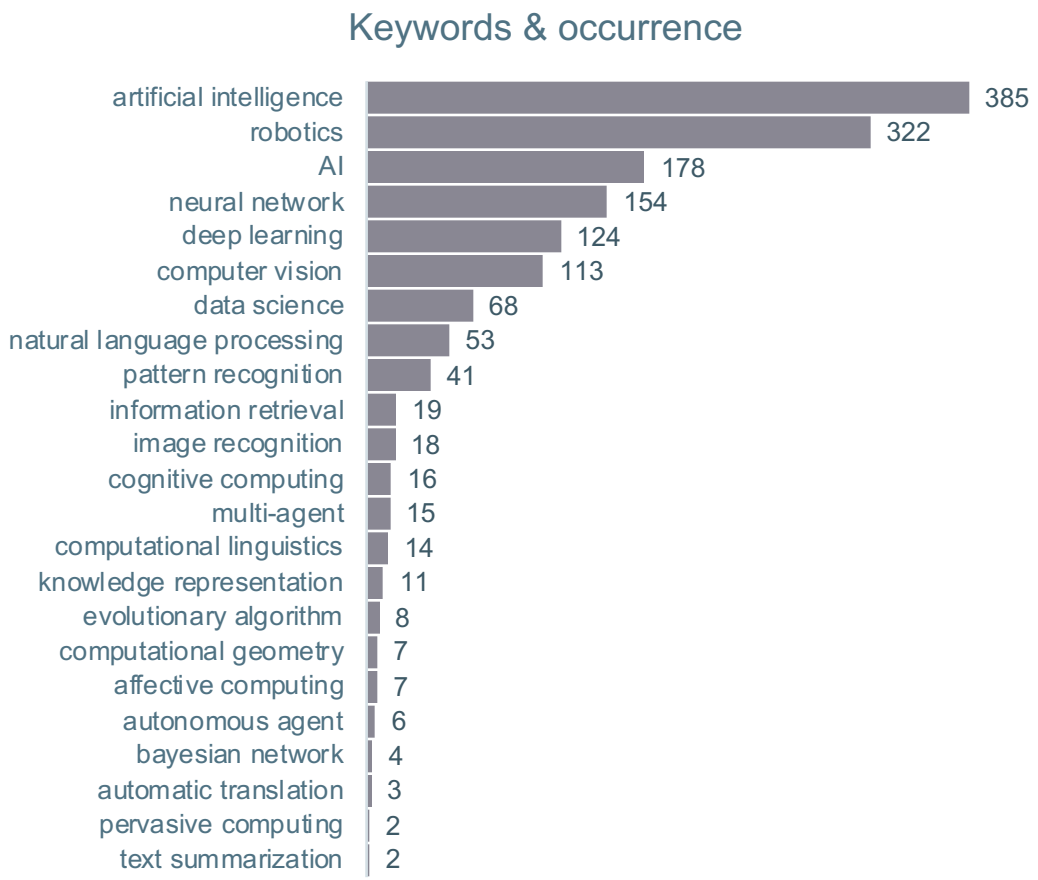
Download: 04-11-2019
Dataset Dealroom: 599 companies

Combining these datasets results in 818 unique companies

Start-up / scaleup categories
- Based on employee information: companies were divided in categories. There is not one single definition for start-ups and scaleups. Some definitions rely on number of employees, others on growth in turnover. Here, study of the dataset led to the following criteria:
  - Start-up (employees >1 and <51): 669 companies
  - Scaleup (employees >50): 67 companies
  - Other (employees > 150): 28 companies. These companies were not counted as scaleups because of age or acquisition.
  - 57 companies had either no company employee information or 0 or 1 employee.

Data was further cleaned manually to remove errors and enrich industry information.

EU Research Funding: Considered research projects 2014-2020



Research project database CORDIS contains all EU research projects under the Horizon 2020 programme and all participating organisations. This includes European Research Council grants.

- 1.549 AI-related research projects selected based on 24 keywords (left).
- These projects connect 3.658 participating unique organisations, 196 from The Netherlands. 423 projects have at least one Dutch partner organisation.
- Total cost of all projects is just over 3,5 B€.
- The total contribution from the European Commission to these projects totals over 2,9 B€. Of this, 198,6 M€ (7%) goes to Dutch organisations.

Source: CORDIS database on Horizon 2020 projects, accessed December 2019

Talent Supply: Considered fields of education in AI and related fields

Artificial Intelligence and Data Science studies in NL:
- B Artificial Intelligence
- B Kunstmatige Intelligentie
- M Artificial Intelligence
- M Data Science for Decision Making
- B Data Science and Knowledge Engineering
- B Data Science (joint degree)
- M Data Science and Entrepreneurship (joint degree)
- M Economics and Business (*Data Science and Marketing Analytics*)[1]

Related fields:
- B Informatica
- B Wiskunde
- B Computing Science
- M Computing Science
- M Mathematics
- M Physics and Astronomy
- B Technische Natuurkunde
- B Technische Wiskunde
- M Physics
- M Applied Mathematics
- M Applied Physics
- B Technische Informatica
- M Embedded Systems
- M Industrial and Applied Mathematics
- M Human-technology Interaction
- M Computer Science and Engineering
- M Econometrics and Mathematical Economics
- B Computer Science
- B Mathematics
- M Actuarial Science and Mathematical Finance
- M Software Engineering
- M Astronomy and Astrophysics
- M Mathematical Physics
- M Computational Science
- M Stochastics and Financial Mathematics
- M Computer Science (joint degree)
- M Computational Science (joint degree)
- M Physics and Astronomy (joint degree)
- M Computer Science
- M Parallel and Distributed Computer Systems
- M Interaction Technology
- M Internet Science and Technology
- M Mathematische Wetenschappen
- M Informatica
- M Computer Engineering
- M ICT in Business and the Public Sector
- B Econometrie en Operationele Research
- M Econometrics and Management Science (*Business Analytics and Quantitative Marketing*)
- M Supply Chain Management
- M Business Information Management
- M Economics and Informatics
- M Business Analytics & Management
- M Data Science and Marketing Analytics
- M Geneeskunde Master Big Data

[1] Master with a track in Data Science. Student population in this track is unknown, the programme is not part of our talent calculations,

Talent Demand: Considered job openings in AI

- Vacancies are provided by Jobdigger's database.
- Selected job openings contain vacancies with at least one of the keywords, see table.
- Database contains vacancies published between 1 January 2018 and 31 March 2019.

Selection steps:

1. Selection is based on presence of 2 or more keywords in position title and vacancy text.
2. Selection is based on specific occupations as defined in International Standard Classification of Occupations (ISCO): three occupations (first 2 digits) are selected.

This selection results in a total of 5.909 vacancies in 2018 and 1.611 in Q1 of 2019.

Keywords used for selection of of vacancies		
• "advanced analytics"	• "computational science"	• "neural networks"
• "affective computing"	• "computer vision"	• "pattern recognition"
• "ai"	• "data analytics"	• "pervasive computing"
• "ai/ml"	• "data mining"	• "predictive analytics"
• "artificial intelligence"	• "data science"	• "process mining"
• "artificiële intelligentie"	• "deep learning"	• "robotics"
• "kunstmatige intelligentie"	• "deeplearning"	• "semantic web"
• "cognitive computing"	• "knowledge representation"	• "speech recognition"
• "cognitive neuroscience"	• "machine learning"	• "tensorflow"
• "cognitive science"	• "machine-learning"	• "text mining"
• "computational geometry"	• "natural language processing"	
• "computational linguistics"		

ISCO codes (first 2 digit) used for selection of vacancies
• 21: Science & engineering professionals
• 23: Teaching professionals
• 25: ICT professionals

Appendix VII

Interview respondents: list of organizations

AgroEnergy
AI Lab One
Airborne Composites Automation
Airbus Defense & Space
APM Terminals
ATOS
Birds AI
CLAIRE
Clockworks
ECT Terminals
Erasmus Centre for Data Analytics (ECDA)
Erasmus University Rotterdam
Doculayer
Dutch Analytics
Fizyr
Fox IT
Geronimo.AI
Gradyent
Janssen Benelux
ICAI
KPN
Landscape
Leiden University
New Compliance
OKRA
ORTEC
Port of Rotterdam
Quantib
Rijk Zwaan
Robin Radar
RotterdamAI
Royal IHC
Semiotic Labs
Shell
Sobolt
Stedin
Technolution
TU Delft
Unilever
Vopak
VORtec
World Horti Center
YES!Delft