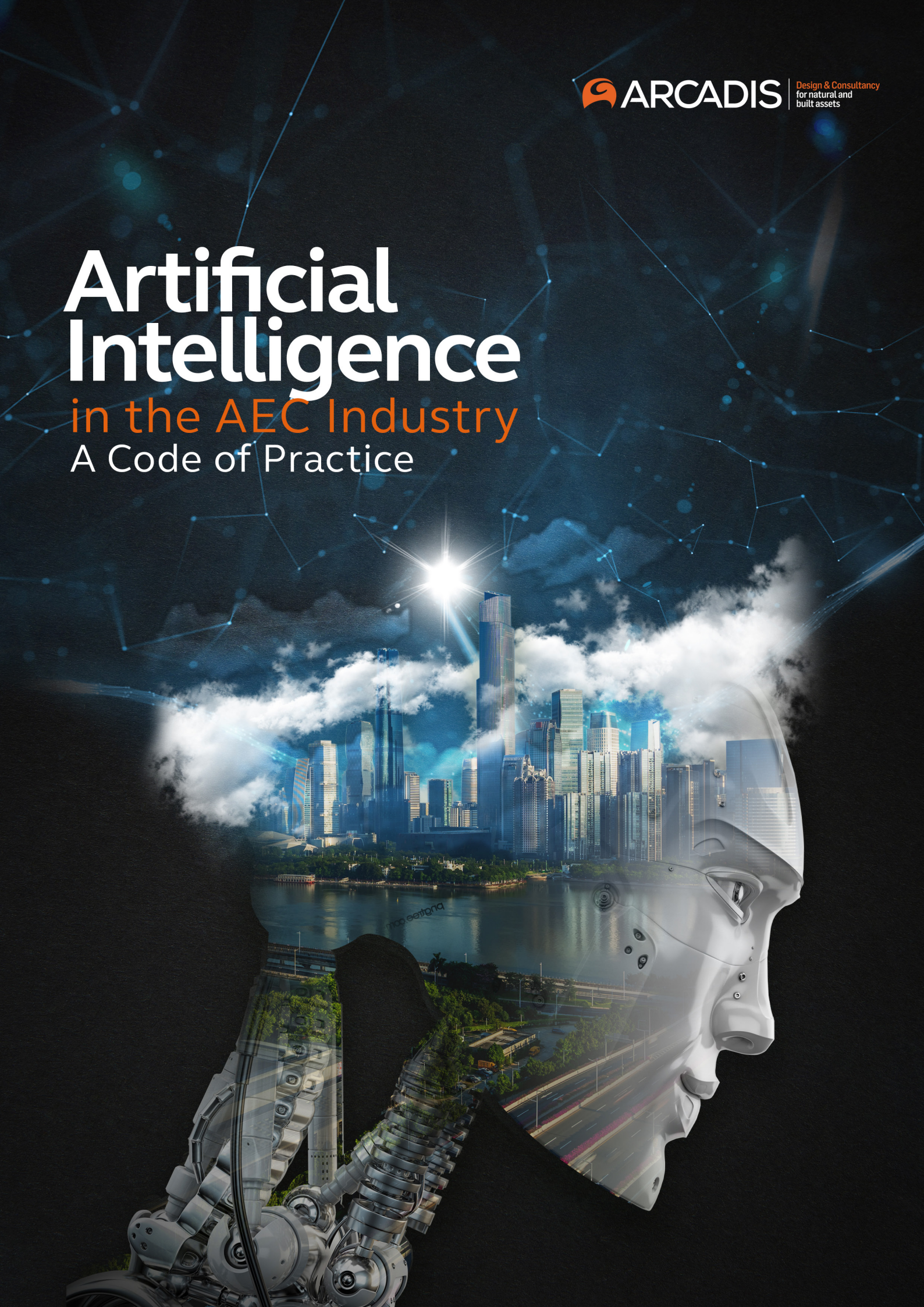
ARCADIS Design & Consultancy for natural and built assets

Artificial Intelligence

in the AEC Industry

A Code of Practice



Foreword

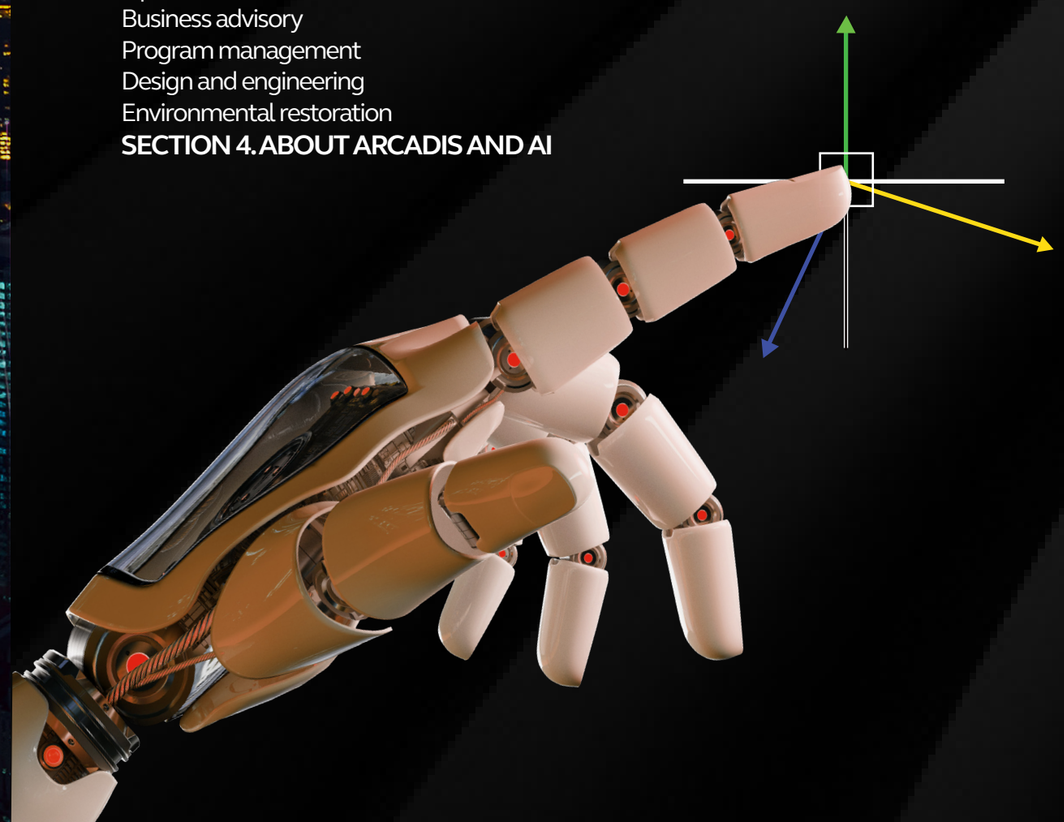
Striving to create a better quality of life for society at large – this is the mission and ambition that we in the Architecture, Engineering, and Construction (AEC) industry hold, being at the forefront of many of large social challenges, whether it is in the development of sustainable infrastructure or the assurance of continued provision of many basic services in every day and crises settings. Our integral roles in the present as well as the future realities of societies require that we continuously seek for enabling tools that help us reach the solutions societies demand and deserve. For us at Arcadis, Artificial Intelligence (AI) comes to play an undeniable role in our solutions and continues to inspire us to build towards a better future for all.

As we speak, cities worldwide struggle with mobility, resilience, affordability, and sustainability issues, all of which grow to be increasingly complex in the face of the global population crises and changing climates. Faced with a changing world, AI and its promises of a transformative Fourth Industrial Revolution quickly grew as buzzwords that reverberated across the business world. Due to its ability to navigate through the complexity of many of our current challenges better than previous technology or sometimes even humans can, the application of AI in social solutions comes with the ambitions of technological interventions to many global problems. Now more than ever, the conversations of AI and related technologies grow to take an even more central stage. Amidst the COVID-19 pandemic, our latest global challenge, it has been made evident that AI technology plays an indispensable role in tackling these complex global challenges, and our societies around the world are accelerating towards a more digital future.

Aspiring towards a stronger industry and a better future for all, we hope the following discussion of present and future possible applications of Artificial Intelligence to solutions within our industry can inspire more to join us in this journey. Fraught with its own complex coordinative problems, the AEC industry needs more visionaries to turn the business towards a more technological future with evermore daring solutions. We believe in the role of AI in striving to have a positive change on the communities we serve and our environment, and in dreaming of improving the quality of life around the world. For all of those aspiring for the same, this is a conversation we want to have with you.

Sarah Wilkes
Global Solutions Lead at Arcadis

Contents

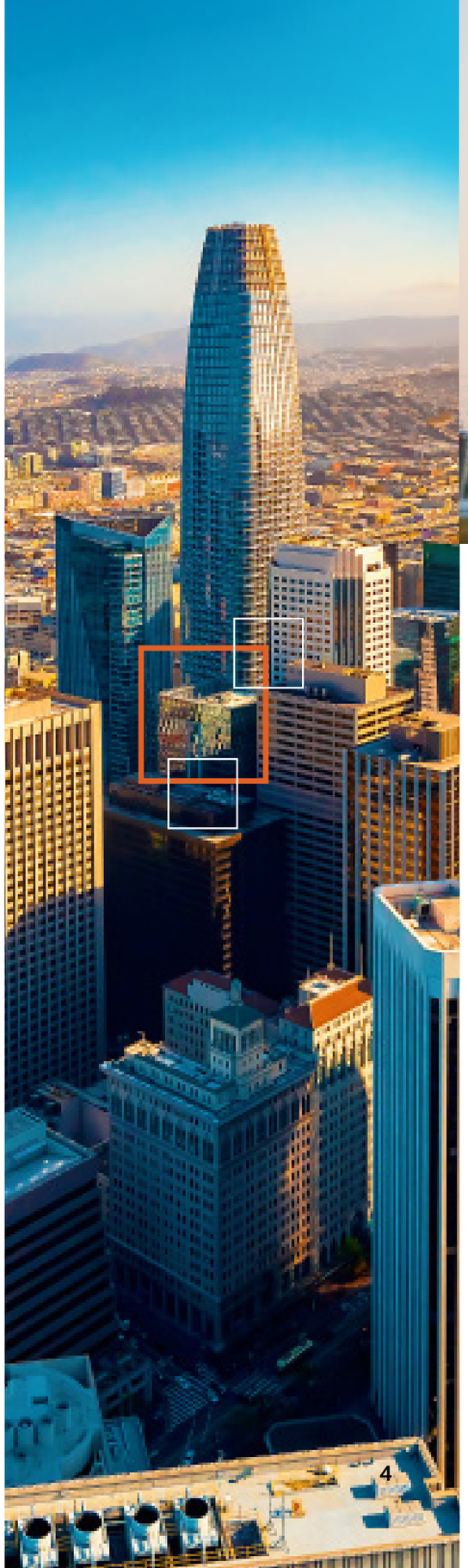


Why Artificial Intelligence?

An Industrial Revolution

In the age of data abundancy, global data availability has boomed, while the cost of data storage and processing has drastically decreased. This enables companies to store and analyze data from sources that were previously unattainable, and thereby obtain more precise knowledge. The AEC industry deals with significant data arising from many projects that include multiple disciplines and (software) technologies that connect information from representations of physical and functional characteristic of the built environment including consultancy, planning, design, construction, operation, and maintenance, and represent physical and functional characteristics of any project.

While companies in the past could utilize customer demographics, transactional data, or data from governmental agencies to understand its users; companies today can utilize real-time data that offer insights about the users' geographical position, their behavioral and communicative patterns, or even their sentiments and values. The data streams today include informal channels where the customers themselves interact with the environment, which enables a more intimate understanding of their motivations and needs. This increase in data availability through a variety of mechanisms, creates large, complex and unstructured data sets. However, due to new powerful advanced analytics techniques, patterns which were previously hidden in the vast amount of data can now be spotted and recorded. As the world shifts towards a more digitized future, the data economy thrives, and artificial intelligence (AI) knowledge increasingly attracts the attention of many firms as an asset to generate competitive advantage. Through applications of AI, companies of different backgrounds in various industries are finding evermore effective solutions, meeting their demands at a faster pace, and tackling larger and more impactful challenges every day. Together with increased connectivity and automation, AI is fanning the fire for a Fourth Industrial Revolution (Industry 4.0).



The digital revolution is occurring across the entire value chain. Within the digital ecosystem there is an increase in data sources, infrastructure vendors, open data platforms which enable data management, analytics platforms and solutions, and lastly, analytics service providers specialized within different use cases. Furthermore, a few players are also creating specialized end-to-end solutions. The increase in data availability and new analytical techniques enables the growth of the digital ecosystem, where the existence of data and AI can be used to tackle large-scale societal issues through more effective managing of natural and built assets. The development of this ecosystem should fuel a movement towards a less fragmented and more collaborative Architectural, Engineering and Construction (AEC) industry to accelerate our collective growth objectives. Open source data is an important catalyst for innovation, it can be considered as a commodity to build IT products and services and can thus be an incentive for business. In combination with technologies it is fundamental to all AI offerings. A centre for open source technologies would dramatically improve the creation, deployment, and management of AI solutions within a company. Therefore, we should – as an industry – be able to collectively share our data, opinions, skills and knowledge to measure, map, analyse, estimate, judge, propose or inter(predict) any processes of common interest. Especially in our industry, the object type library (OTL) is a good example of standardized object-type names, properties, specifications, accompanied by object-type data, geometry data, and metadata which is very promising for the business and can increase efficiency and the speed of innovation radically in the field of AI, if information is shared on an open source basis.

But is our industry able to establish common, open, modular standards (such as a grid), allowing collaborative efforts across networks in which everyone designs for everyone? Universal (open source) standards also encourage remote collaboration which is essential in today's world. How can we bring our architects, designers, engineers, consultants, manufactures, and builders together to develop the best, most straightforward and high-performing assets, integrated with technology that everyone can use and improve, to enable a truly sustainable built environment? It's time to challenge the status quo!

Freek Matheij
Washington DC, USA

Freek is the Global Data Analytics & Automation Lead for Arcadis. Freek has 10 years of professional experience, having worked in Design & Engineering, Information Management and in the Digital Transformation field. He focuses on implementing the data analytics strategy in the company, challenging the status quo to further automate the business and make an impact.

Susanne Knorr
London, UK

Having 7 years of professional experience and a strong natural science background, Susanne is the Global Data Analytics Client Development Lead. She focuses on key opportunities to apply Arcadis' Data Analytics services across all sectors and solutions to help clients address their challenges and enhance their performance.

A Paradigm Shift

As mentioned by Yuval Noah Harari in his Financial Times article "The World After Coronavirus"[1], humankind is facing the biggest crisis of its generation, and the decisions people and governments take now will probably shape the world for years to come. According to the author, there is a need to act quickly, and decisively, while considering the long-term consequences of our actions. Considering such uncertainties, where decisions that would take years to be made are passed in a matter of hours, new technologies are pressed into service. The task of navigating in this time becomes intricate as it becomes increasingly difficult for companies to predict future developments, and the agility and resilience of businesses have become key for their survival.

With growing global crises such as population growth and climate change, our handling of uncertainties extends way beyond the COVID-19 pandemic and is likely to be the new paradigm. As we are heading towards a population of 8.5 billion by 2030, from which roughly 70% will live in cities, and where working from home might become a new accepted form of working, many questions grow evermore pressing. How will the industry be affected? How can we improve the quality of life in the light of these issues? How can we help create better spaces and cities facing the uncertainties and challenges of our future? Catalyzed by the paradigm shift towards technology during the current pandemic, AI and other technologies such as IoT will be imperative in solutions to future challenges comprising unforeseeable complexities. Ultimately, these technologies have an undeniable role in the transition from the current unsustainable models of urban life to new forms of collaboration, dynamics, and lifestyles.

The Need for Disruption

Despite a changing world, the Architecture, Engineering and Construction (AEC) industry has been laggard when it comes to digitalization. Numerous studies including a 2015 McKinsey Global Institute[2] study ranked 22 industries based on their levels of digital disruption and one can find the AEC industry at the second from the bottom of that list, only to be followed by "Agriculture & Hunting". One reason for this time lag in the adoption of digital technologies might be found in the fragmentation of the industry with many small players and few large firms. The fragmented industry means that the financial resources for significant Research and Development efforts and the implementation of new technologies is more difficult to achieve in AEC compared to industries that are more concentrated. Moreover, the statements, "but we are building things…!" or "every project is unique..!", are often used to justify that the AEC industry can lag behind on the digital transformation due to the lower dependencies on technology compared to frontrunner industries such as Banking, Retailing or Transportation. The notion is that digitalization is more relevant for customer-centric Business-to-Consumer (B2C) businesses where business models can be entirely based on digital products, but that such digital solutions cannot be easily applied in true concrete and mortar industries, where viability and general focus are usually on tangible assets. As a matter of fact, too often, stakeholders from within the industry forget that the AEC industry is fraught with very complex and difficult problems in our society that could benefit from powerful digital capabilities to support in addressing these problems.

Technology trends and developments in other industries are also accelerating the disruption of our industry, which is creating massive business opportunities and refining the human experience across all aspects of the AEC industry. Not only does new technology offer the possibility to optimize the current workflow, it also enables a change in the value chain. Development in other industries have shown how digitization restructures the value chain and leaves certain steps obsolete. Perhaps the future AEC industry offers services directly to clients, or that the offerings will differ significantly in other ways. In order to stay on top of this disruption, true understanding of the human needs and an innovative approach to how digital capabilities can solve these are needed.

[1] Harari, Y. (2020). Yuval Noah Harari: the world after coronavirus. Financial Times. Retrieved from https://www.ft.com/content/19d90308-6858-11ea-a3c9-1fe6fedcca75

[2] McKinsey Global Institute. (2015). Digital America: A Tale of the Haves and Have-mores. McKinsey & Company.

Since the publication of the 2015 McKinsey study, there has been a lot of change in the AEC industry. Digital technologies and capabilities have been tested and scaled across many different applications. Transformative technologies are being developed and compounded every day from a range of foundational technologies from a variety of fields: AI, software and computing, data and connectivity, advanced materials, manufacturing, energy, and mobility. Among these foundational technologies, many are underway and create working demos for industrial application as the need for a digital transformation demands their adoption, some good examples are:

Geographic Information Systems (GIS) are used to capture and analyze spatial data

Building Information Management (BIM) has increasingly replaced paper-based drawings and has increased collaboration across teams. Light Detection and Ranging (LIDAR) and other laser techniques has enabled the industry to build 3-D Models out of anything, which leads to the ability to visualize and model any asset.

Generative design frameworks exploiting big data analytics and AI to parallelize algorithms for real time GD computation.

Internet of Things uses a collection of tablets and sensors to collect data from large sites. While the collection of this data is not a new process, IoT enables a larger collection of updated, real-time data.

Cloud computing and AI will melt into one another, disparate servicers which are part of cloud computing technology hold data which AI can access and use to enhance learning and make decisions and in the end can impart this new data in the cloud which can help other AI systems again.

Drones have offered new opportunities in collecting visual overviews of sites and have revolutionized the way we inspect assets or monitor large sites. Furthermore, the accessibility of increasingly more affordable satellite images aids this process.

Augmented Reality (AR) and Virtual Reality (VR), which are also known as Extended Reality, have been applied to enhance customer experience and improve the workflow in many design projects. Holobuilder and virtual glasses can be used to create a virtual tour of a site, which can be shared with the project manager or the client.

Smart buildings with personalization services using AI, mobile apps and visualization to exploit the possibilities of processing complex events.

Improvements in Data visualization streamline communication with clients and the decision-making process. Interactive dashboards provide better insights.

Customer Experience (CX) or Human Experience (HX), using design thinking approaches, have entered the AEC industry in a way that allows us to design, build, operate and maintain assets in a more citizen- and user-centric way.

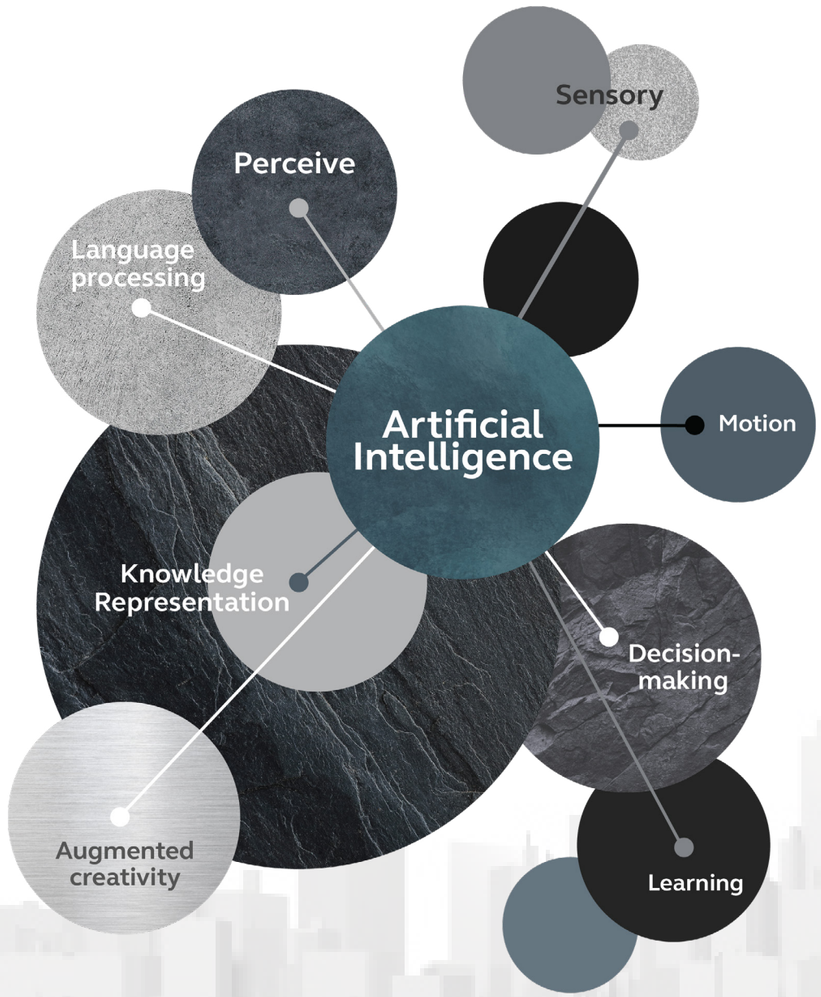
Other value adding services are clash detection and resolution, social networking services and analytics, personalized services (platforms), facility management, energy management and analytics.

Approaching a new horizon, two new and potentially even more impactful capabilities in the AEC industry than are Data Science and AI, both are growing in their own imperative to adoption. The necessary next step is to combine these skills with many of the technologies and capabilities mentioned above to enable more powerful value propositions and generate deeper insights, in order to further digitize the industry.

The Eight Challenges of Artificial Intelligence

With its core role in the Fourth Industrial Revolution (Industry 4.0), AI has risen to be a buzzword across all industries, and with it come the interrelated concepts of smart cities, intelligent water, smart mobility, digital twin[3] etc. The concept refers to the creation of intelligent computer systems that can mimic human intelligence in exhibiting reasoning, perceiving, decision-making, generating novel ideas, or operating machineries. Building systems that break human intelligence down into smaller subsections, research and development in AI can be subcategorized into eight major areas in the simulation of human cognitive processes: perceiving, sensing, processing of language, moving, representing knowledge, making decisions, creating, and learning.

As AI technology develops within each of these areas, algorithms are replicating tasks that can be intellectually challenging, which enables the experts in the field to do their jobs better, more efficiently, more accurately, faster, and more reliably . The AEC Industry is no exception, and there are impactful examples for how AI capabilities have reshaped the AEC industry in each of these eight areas and how they have been applied across projects and at scale.



[3] Digital Twins are virtual models of a process, product, service, building, or city. The pairing of the physical and virtual worlds allows for greater analysis of the physical world within multiple scenarios and simulations. Digital Twins are maturing as more data sets continue to be available through the proliferation on the Internet-of-Things. Advances in computing power, and eventually Quantum Computing, as well as advances in Machine Learning will enable the simulation of increasingly complex models and scenarios.
Digital Twins of cities are referred to as Virtual Scenario Platforms (VSP) which can provide live simulations of events and real-time asset monitoring.

SENSORY Simulation of human senses to perceive environmental stimuli:
Moving towards real-time analytics, which will become increasingly important to the AEC industry, will require a vast amount of real-time data feeds. Internet of Things (IoT) is providing these real time feeds for many variables already. We have been developing use cases around bridges, rail switches, groundwater, utilities and other asset types. At Arcadis, our colleagues have been combining weather data and water level sensors to predict water demand and supply and potential shortfalls – an example illustrating how IoT can be combined with external data to enhance the sensory understanding of an environment.

LANGUAGE PROCESSING Processing of human-generated stimuli:
Making algorithms understand can involve automatically reading through large amounts of text (that, given their sheer size, are either not feasible to read or not economically viable to being read by a human) and to identify and synthesize useful information. Natural Language Processing (NLP) has proven to be an important method which can be applied here. The AEC industry is a very document-oriented industry, with submission of drawings, reports and other paper to meet the requirements of the contract. Hence there is a myriad of potential use cases for NLP. Think of requirement documents, tender documents, or project reports that must get processed, all of which can potentially be automated and digitized.

PERCEIVE Simulation of human affects to recognize and interpret environmental stimuli:
One of the key analytics capabilities that has been adopted by the AEC industry, is the one of computer vision – which is often referred to as image recognition. Traditionally labor-intensive tasks in AEC, such as physical inspections, are automated using digital inputs and an algorithm capable of recognizing and processing the information available in said inputs. By applying machine learning, computer vision can be trained to make decision following an iterative learning process based on its own operations as well as input human knowledge.

KNOWLEDGE REPRESENTATION Make available structured and unstructured knowledge in appropriate representative form: Given the fragmented nature of the AEC industry, it has been notoriously difficult to aggregate and institutionalize knowledge. A lot of the knowledge within the industry is based on the subjective, incomplete, and inefficient communications between partners of diverse goals and backgrounds. Better knowledge management and the creation of databases that are used across organizations and made accessible to those who rely on it is therefore of crucial importance in effective delivery of services across the industry, as well as for the communications and knowledge sharing within the ecosystem.

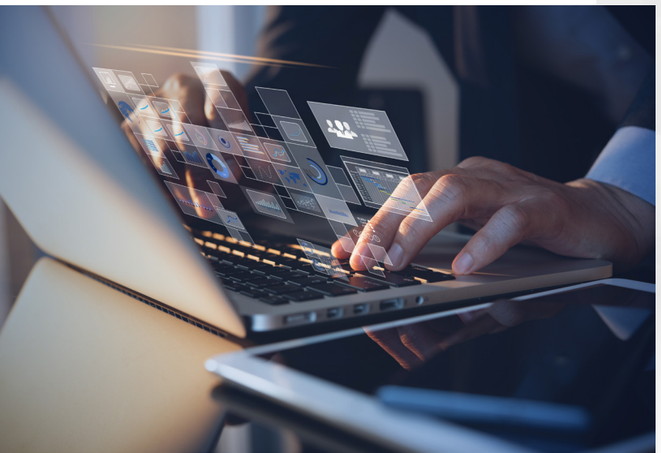
LEARNING Algorithmic learning to perform tasks without explicit programming:
There are many use cases across the industry where machine learning is applied to learn from the past. One of the most prominent areas is predictive maintenance, where historic data is leveraged to predict whether failures are about to happen. Within the management of assets predictive analysis can greatly reduce uncertainties and optimize asset operation and maintenance. The implementation of such algorithms requires the availability of real-time IoT data feeds, which is still in a conceptual stage and some proofs of concepts are being developed.

DECISION-MAKING Autonomous decision-making in complex problems considering various factors:
This element of AI, is moving towards the most complex part of advanced analytics: prescriptive analytics. Whenever historic data is used not only to predict what will happen but also to prescribe the best solution, AI-based support is used. This support can either autonomously make and implement decisions in real-time or work as an aiding tool for decision makers. Stakeholders and senior management team can make decisions with more certainty by utilizing real time dashboards offering future predictions and recommendations based on historic data. This can be applied in various optimization projects across the industry, for instance when it comes to the asset renewal plan for the next 10 years and the optimal way to invest in new and maintain existing assets.

AUGMENTED CREATIVITY Creation of novel output independent of human supervision or direction:
Given that design and architecture are crucial to the AEC industry, this AI capability is of great importance. The industry has been gradually moving from BIM into parametric design to computational and eventually generative design. This helps architects and engineers to quickly generate a range of design options and to select and communicate the best option for their clients – and for the citizens.

MOTION Independent movements in uncontrolled environments:
Within the AEC industry, there are many use cases where costly human labor can progressively be replaced and augmented by machines – this is particularly relevant for physically moving through cities, assets and sites, for instance for state inspections using IoT sensors or even autonomous drones. The complete autonomy in mobility is still in its infancy but many firms have been experimenting with it and have invested in relevant start-ups within the AEC industry. The consideration of autonomous vehicles will also have a strong relevance for the architecture and engineering of future infrastructures.

These capabilities testify the power of AI and how it has brought us the beginning of radical change and as an initial guide to AI, in order to expand our discussions further on the applications of them, we first take an initial deep dive into each main capability to learn more about the most prominent technologies in use and their future developments. We do this together with our technical experts and AI enthusiasts from around the world, who want to share their passion and knowledge with you. Following that, together with our subject-matter experts, we explore the combinations of these technologies that are helping people within the AEC industry tackling everyday problems to grander challenges, and also answer the question of "Where do we go from here?". Simultaneously, we share with you our case studies and work from our ecosystem partners to inspire and bring tangibility to these seemingly futuristic narratives. In fact, steps towards an AI transformation have already been taken, and we want to drive forward the effort of AI and the tidal shift in technology within our industry by sharing our knowledge and stories, and taking you on this journey with us.

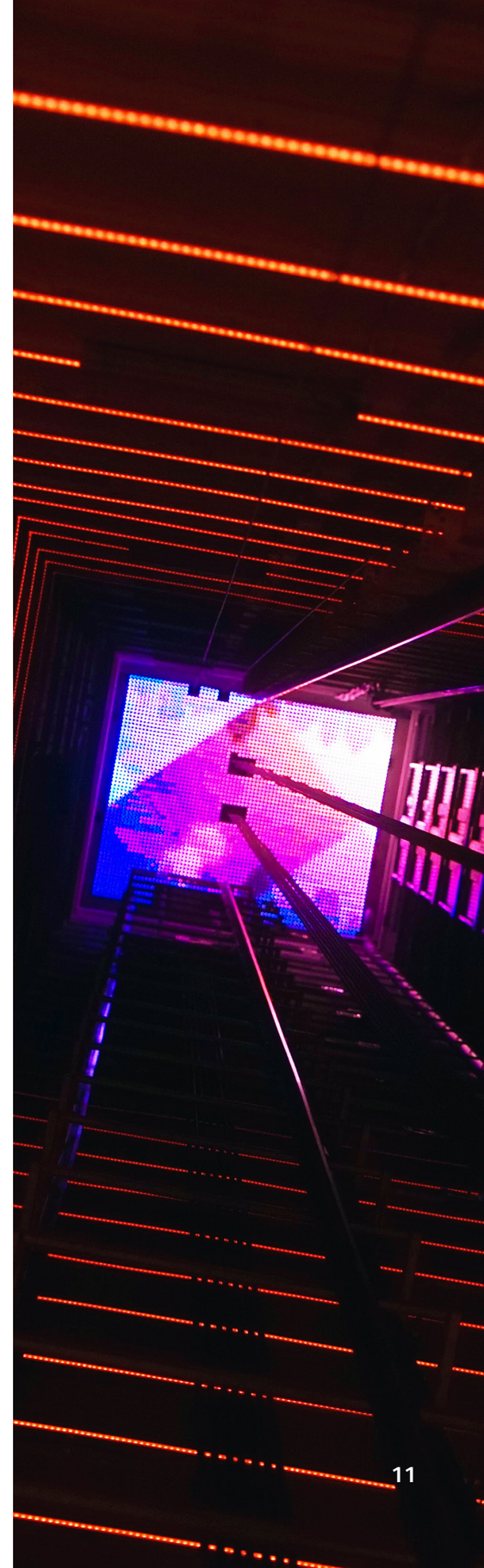


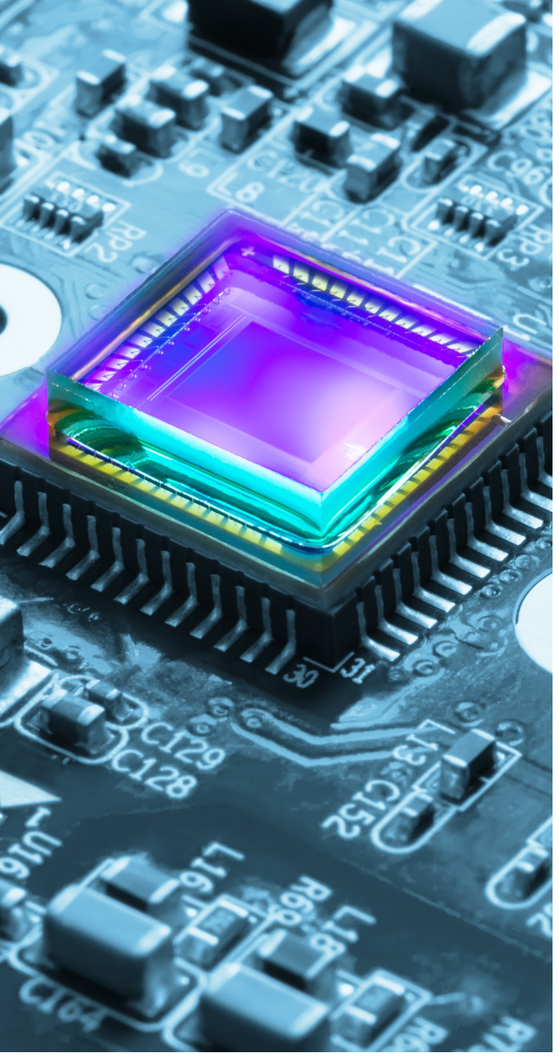
The Main AI Capabilities in the AEC Industry

The interest in AI in the AEC industry has ramped up in recent years with the increasing demand for the AEC industry to process large amounts of diverse data to extract insights applied for better decisions and state-of-the-art improvements on daily operations to larger investment problems. According to a 2020 study[4], the current AEC industry is increasingly focusing on areas of AI such as genetic algorithms, neural networks, fuzzy logic, fuzzy sets, and machine learning. The most common applications of these capabilities include optimization, simulation, uncertainty management, project management, and bridge engineering. However, with increasing interest from scholars, technical, and subject experts alike, future application of AI capabilities in AEC is in no form limited to these applications. Many other emerging topics are beginning to gain traction, such as robotic process automation, digital twin, autonomous vehicles, convolutional neural networks (CNN), and energy applications such as Microgrids, Advanced Battery, and Solar Technologies. In general, AEC capabilities are taking place across all eight previously discussed areas of AI, whether it is in mimicking the abilities of human perception to augmenting creativity, and in combination with each other they produce solutions to many of our challenges in the industry.

Before further researching how the capabilities can be combined, the current section will be a deep dive into these recent as well as potential AI capabilities within the industry, guided by our technical experts. Each article takes a glimpse at the what the technology is capable of, where is it going in development, and how it can support in solving problems within the AEC industry.

[4] Darko, A., Chan, A.P., Adabre, M.A., Edwards, D.J., Hosseini, M.R. and Ameyaw, E.E., 2020. Artificial intelligence in the AEC industry: Scientometric analysis and visualization of research activities. Automation in Construction, 112, p.103081.





SENSORY

As humans, we often rely on data to make our choices, but we let our beliefs, intuition, and experience guide us as well. On the contrary, artificial intelligence solely relies on data and its algorithms to provide answers to questions. As such, generating and collecting data on assets becomes crucial in order to fully leverage the power of AI and develop new insights. In fact, to form a diagnosis on a problem (just like in a medical context), it is first necessary to generate a broad range of data points from the physical environment. So far, manual and visual inspections of assets have been used as a method, but the amount of data collected is becoming insufficient with the amount of analytics and insights expected. Infrastructures are being built following much more stringent demands and using advanced calculation tools to reduce material usage and push engineering to the limit. To be able to perform such calculations and to keep track of assets in more detail, our demand for more data points is growing.

The Internet of Things (IoT) is of great support in this context. The technology relies on a network of embedded sensors and other devices with network connectivity, capable of sending and receiving data about changes to the asset and the current environments around them. The capability of sensors of providing constant real-time data allows real-time monitoring and inspection and, in turn, data-driven decision-making using AI.

Sensor-based technology allows us to sense and capture much more data than humans will ever do. Indeed, sensors are ubiquitous, even in unthinkable places. For instance, a normal mobile phone contains over 10 different sensors that enable interactions based on translating physical input into electrical signals: unlocking the phone with a fingerprint, using the touchscreen, navigating using GPS. The same technology can be applied to assets in the AEC industry, of course in a much more advanced state than the one included in a phone. Indeed, the data points collected allow companies to measure deformations of a bridge, measure air and water quality in the building, detect vibrations, and more.

For instance, traditionally, during the construction phase, spirit levels are adopted to ensure an object is constructed horizontally. Although this method is sufficient during this phase, calculation models have shown that objects move and deform due to external forces and changes in temperature. A possible approach to solve the problem involves applying accurate tilt sensors to an asset such as a bridge. Being at their core very accurate spirit levels, the devices can measure changes very precisely: it is possible to measure if a 200-meter-long bridge is 1mm lower on one side compared to the other. These sensors are uniquely designed for the measurement of infrastructure and can show the dynamic change of the bridge over time, and measure how seasons and water tides affect the bridge. The data points are then fed to the mathematical models, allowing for accurate calculation of the remaining lifetime of the asset or to signify if not predict when maintenance is necessary.
By allowing to measure multiple aspects of a physical asset, sensors provide a detailed overview of its state. In certain cases, this combines with analytics which enable predicting failures by leveraging the power of AI. For instance, sensors can be applied to the motors of a bridge to measure voltage and current, as well as environmental factors that could influence the performance of the device. The combined information can be then fed into the machine learning algorithm, to develop an overview of the expected motor power usage. Unforeseen discrepancies with the expected value provided by the model can indicate future failure. This information would enable predictive maintenance and would reduce disruption, save time and costs.

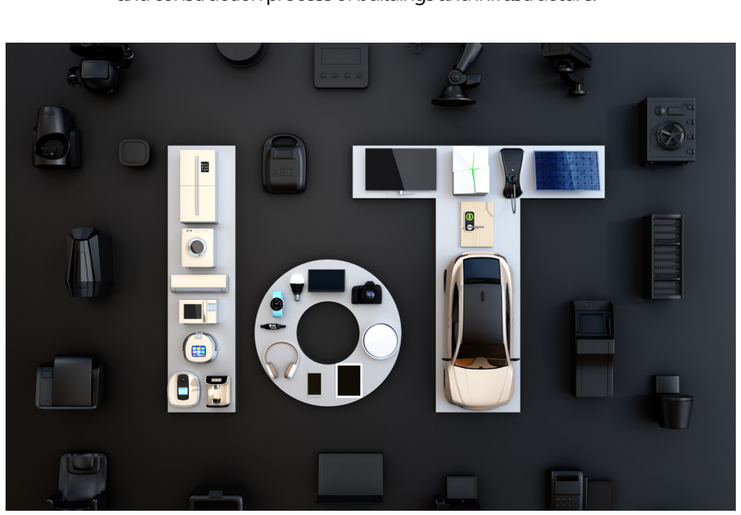
Joost Kuckartz
Amersfoort, The Netherlands

After a PhD from the University of Melbourne, Joost joined Arcadis in 2016 as an Internet of Things (IoT) consultant. He currently works with organizations across the built environment to implement IoT, to create smarter use of information including data science, develop visualization tools, structural health monitoring and other applications that use sensors and data in a unique manner.

This example is just one aspect of the well-researched area of Structural Health Monitoring (SHM), also known as asset monitoring, which focuses on the engineering and construction aspect of the AEC industry. However, IoT is also able to support the architecture phase by, for example, providing constant information regarding the use of the building. Indeed, by collective information on aspects such as which rooms are more used, what is the indoor air quality or temperature, it is possible to design more efficient and productive buildings. Moreover, by integrating IoT with applications and software, it is possible to allow users interact with the environment in order to adapt it to their needs. Such considerations form part of the Smart Office field, which aims at improving the living conditions of an office.

Ultimately, IoT enables real-time data analytics and AI by constantly capturing stimuli and information from the environment. However, merely "sensing" external factors and collecting data is not enough. Data needs to be transmitted, stored, and used. Furthermore, visualization is a key phase, as this enables decision making. It is no surprise, therefore, that digital twins – digital representations of the physical world that includes real-time data from IoT – is already a prominent topic in the area, and that will become a key aspect of the design and monitoring process in the future. Indeed, digital twins will allow us to have a better overview of the assets, hence improving decision-making and the management of the complexities of such systems. Furthermore, recent improvements in BIM and AI foresee a greater integration between the two areas in the future. AI will be able to significantly improve and speed the design and construction process by elaborating big data collected through IoT and provide data-driven decisions regarding the design process and tasks which do not require the intervention of humans.

Looking further ahead, IoT will also be crucial in enabling further development of sustainable and futuristic smart cities starting with smart water, which indicates water conveyance systems operated by data-driven technologies. Indeed, the application of IoT, AI, machine learning, and predictive analytics will greatly improve how we manage water ecosystems within cities. By collecting constant real-time data on the system thanks to sensors, it will be possible to monitor the consumption levels within a community, give insights on the effects of changing policies, and improve the treatment process management. Intelligent water will then serve as a foundation for the development of smart cities, whose focus is to leverage information and communication technologies to enhance the quality of life within urban centres. As more and more cities investigate the possibility of developing into smart cities, the AEC industry needs to take into consideration how to integrate this need within the design and construction process of buildings and infrastructure.



CASE STUDY

Dordrecht road bridge monitoring

To execute a safe and efficient asset strategy, it is essential to have a complete and current report of the asset's status. Liaising with our partners in the SHERPA collaboration, Arcadis assisted in the installation of sensors on motors and the bridge deck to keep track of full bridge operation for a key road bridge in Dordrecht, The Netherlands. Information from the sensors is transmitted securely, without the operational elements of the bridge being connected to the outside world. This separated monitoring system setup limits from any malicious outside actors and was approved by the governmental organization for future installations at other assets as well.

The bridge was instrumented with various sensors monitoring power, current, voltage, bridge cycles, deck position, wind data and water temperature. Using the information, data models were created to indicate normal operational levels, for future data to be compared with. Further to prevent data transmission from being intercepted from outside actors, the sensor data was not integrated in the existing system but a standalone monitoring system was developed that only transmits data one-way. The receiving data hub uses specific secure transmission identifiers, which required specific setup of the sensor system but also back-end modifications to allow the sensor data to be received. Besides the unique sensor installation on the motors and the bridge deck keeping track of full bridge operation, weather data was also introduced for correlation and modelling analysis. Following this, a live dashboard of all collected data was produced. Lastly using the measurements and data analytics capabilities, predictive modeling was executed and Arcadis was able to predict an impending failure three weeks before it occurred.

Through readily available and real-time performance data, data-driven decision making is supported with regards to the asset. Furthermore, through the measurement of motor power usage during multiple opening and closing actions, we identified impending failure before it occurred through a predictive model. Using this model, the client can prepare its maintenance schedule and significantly limit road and waterway disruption. In addition to minimal disruptions, the cost of operating and maintaining the bridge is also reduced as usability is improved and unplanned maintenance minimized. The cost of on-site inspection is also reduced since measurements are automatically collected to find anomalies for further investigations. Finally, since data-collection is automatized, health and safety standards are improved as physical inspections are minimized.

CASE STUDY

Niricson

One of the biggest issues of Asset Management is aging assets. Due to a series of external economic factors such as the financial crisis in 2008, investments in asset maintenance have greatly decreased, forcing organizations to "do more with less". Aging assets have been posing several challenges for both the public and private sector industries in the last decade and have resulted in many infrastructures collapsing around the world leading to hundreds of people dying as a result.

A major complication contributing to the issue is the current inspection process which relies on the visual inspections of workers who carry field assessments of the assets. Niricson aims to help infrastructure owners to solve this issue by working in conjunction with the current inspection process to overcome the challenges they face. This is done using a proprietary damage assessment software, paired with a patent-pending drone-based data collection technology.

The drones can collect multilayer data, by capturing optical and thermal images, acoustic signatures, positional information, distance measurements, and climate information. The collected data is analyzed through the software, which allows for automated damage detection and quantification using machine learning. In turn, Niricson's solution provides objective and quantifiable reference data that can help guide asset owners to make informed decisions for safer operations of their assets.

Niricson's technology significantly improves the entire inspection process leading to a 5-7x faster procedure than the traditional inspection. This is due to the automation of the data collection process, which allows for the inspection to be more accurate and is capable of mapping defects with minimum errors. Consequently, the reduced time investment helps to drastically reduce costs, with an average cost savings of 50% compared to the current solutions. Ultimately, Niricson's solution allows for predictive maintenance, allowing engineers to objectively assess the severity of the defects, monitor changes, and act before it is too late.

LANGUAGE PROCESSING

Natural Language Processing (NLP) is an interdisciplinary field concerned with the interactions between computers and human natural languages. In recent years, NLP is gaining a lot of popularity and there is a continual increase in its valuation as businesses begin to comprehend its immense potential to understand and analyze human language. Benefits may range from improving operational and production efficiencies to gaining a competitive advantage through effective data analysis and developing new insights. Everyday NLP applications can be found all around us like autocorrect, spell check, autocomplete, translations, online search, voice assistants, chatbots etc. Google search is the most used NLP application with a user-friendly simple interface; the back end of this search algorithm is structured using a powerful transformer model called BERT. Researchers all around the world are introducing new variants of their architectures by fine-tuning the layers and parameters. In recent years, NVIDIA, Microsoft, and Facebook, releasing their mega models with tens of millions of parameters indicate a breakthrough in the field of NLP.

The AEC industry comprises of many large organizations which operate at a great scale. Compared to other industries it relies heavily on textual data in a very unstructured way. Knowledge exchange and communication between the stakeholders is highly important and can take many forms. This highly unstructured and flexible way of working produces very diverse documentation and reports. While this allows for a very adaptable way of working, it also poses difficulties when trying to organize and store this knowledge in a way that is future proof and digitally friendly. Interestingly, a shortage of data is one the limiting factors of NLP models, which due to the complex nature of text require large training sets. This is exactly why industries like ours can benefit the most out of NLP, since text is at the core of our business, we have access to large datasets of documents to develop tools based on their processing, and in turn support our practice.

Deepak John Reji
Bangalore, India

Deepak is a machine learning engineer working on data science projects with a focus on natural language processing and optimization.
He has completed a study in electronics and communications engineering.

Afreen Aman
Bangalore, India

Afreen is an environmental consultant with a master's degree in environmental engineering and a PG Diploma in environmental law. She has been working for 4 years in the advanced analytics team on various environmental digital projects.

One of the most immediate and time-saving applications of NLP within businesses is the automation of routine tasks. For instance, sentiment analyses on the feedback/reviews/comments received from the clients and customers, and social media content helps businesses in working on their weaknesses and increasing their strengths. Towards automating daily roles, NLP techniques can identify necessary information from multitude of textual data and help in formulating reports. Replacing note-taking, minutes after a meeting, reports can be prepared by using speech to text dictation. Stock market analysis by using historical stock price data, reports generated by companies, news articles, etc. can help companies get a hold on real time information on stocks by classifying the news and connecting it to the concerned companies. Combining with analytics, the information collected can be used to predict and notify the shift in market trends based on recent events and news to inform strategic and financial decisions. With the AEC industry still having a lot of reliance of a multitude of human-generated sources (e.g. field report, historical summaries, design reports, bill of quantities), this technology is highly relevant for project management and general advisory functions, particularly with older assets that whereby large proportions of recorded information are not automatically and digitally available.

For user experience and marketing, chatbots can be trained to have an ability to perform personalized conversations and troubleshoot their problems. NLP can help in identifying potential customers by analyzing the digital footprint (browsing behavior, social media posts, keyword search etc) and aid companies in strategizing ad placement for identifying new audiences and use their advertising budgets effectively. By integrating NLP with websites, user experience can be improved by helping the user in navigating through the site using techniques like autocomplete, spellcheck and autocorrect. For HR professionals, NLP can aid in filtering out relevant resumes by using semantic analysis and find the perfect fit.

The era of modern NLP started in the year 2013 with the breakthrough research of Word2Vec[5]. The pre-trained Google word2vec model was trained on Google news data (which contains around 100 billion words); it contains 3 million words and phrases and was fit using 300-dimensional word vectors. Based upon research, it is possible to establish a relationship between words through the trained neural network model. The vector representation of these words was stored in the embedding layer and this paved the way for all further discoveries. After Word2Vec, Glove replaced the traditional way of one-hot encoding. Advances in deep learning, especially Recurrent Neural Network (RNN) and its subtype Long Short-Term Memory Networks (LSTM), gained popularity by solving the real word problems such as language translation, classification, and speech recognition. Attention-based network gained popularity around 2015-2016 and it specifies the subset of the data input. Attention networks deliver breaking performance on many NLP tasks like Neural Machine Translation, Language Modeling, and Question Answering problems. The evolved Transformer model which was introduced in the year 2017 dominated the entire architectures and led to the current state in NLP, the era of BERT, XLNet and others.

Pre-trained language models and transfer learning has made the work much easier in most of the NLP use cases. These architectures exceed the state-of-the-art scores for most of the task-specific benchmarks (based on GLUE benchmark leader board). The most impressive use case was Question Answering and BERT's model score for SQuAD dataset. QnA has a lot of other applications such as Information retrieval, entity extraction, chatbots, dialogue system etc. Customer support and other FAQ mechanisms are extensively leveraging the power of Chatbots and Virtual Assistants. They offer good user experience and smart answering and it replaces the human effort. Apple's Siri, Microsoft's Cortana, Amazon's Alexa are now part of our day to day lives. The majority of these technologies synthesize the speech commands and retrieve specific information using complex NLP language models.

Most of the advanced models can process the context of the sentences thereby removing the unnecessary conjunctions and joining the appropriate phrases and sentence parts. The efficiency of text classification has improved with these advanced architectures. The most common text classification applications are sentiment analysis, spam recognition, document labelling, and Named Entity Recognition (NER). Classifying the sentiment of the text is often challenging as these tasks are always subjective and there is no clear rule for it. Often the business needs to analyze attitudes, preferences and even moods. The models try to find the relationship between words and sentences and when they are properly annotated, it retrieves an excellent result.

With many generic language models in the market, it got increasingly easier for developers to train the model for a specific task. As the model is universal it identifies the specific instances and even translates into different languages.

So, what is next in NLP for business? A lot of companies have carved out many NLP business applications and used them to improve business intelligence. Most NLP methods are statistical by nature so there has been a continuous research and development effort to integrate context and semantics with statistics, which it is growing more powerful and effective every day. The algorithms that are currently used simulate human understanding based on the data used for training, but they can only be as good as the data they encounter. The future of this field will be focused on developing a deeper understanding of the concepts on par with human intelligence. While the future for NLP is in works, the current NLP technologies provide businesses with lot of useful solutions. Thanks to it, our interaction with computers has become more natural and intuitive, which makes analysis and digital information more accessible to everyone. As communications with technology is woven seamlessly into human lives in the future, the understanding of this communication through NLP enables the transformation from a data-driven to an intelligence-driven approach. This will continue to reform communication technology in the coming years.

[5] Mikolov, T., Chen, K., Corrado, G. and Dean, J., 2013. Efficient estimation of word representations in vector space. *arXiv preprint arXiv:1301.3781*.

CASE STUDY

Site summary

Site Summaries are prepared to aid in the strategy development and bidding process for environmental remediation services. They provide details about location, contamination source, site conditions, remedial activities, clean up goals by referring to various historical documents. During a proposal phase for large projects or during the transition of a legacy project, contractors are provided with access to historical documents to review and assess the progress at the site, in order to develop a remedial strategy and estimate associated costs. Technical staff will review the documents and generate a Site Summary consisting of a Microsoft PowerPoint slide deck including both images and text, as well as an executive summary for the technical and management team. This process is usually labor intensive to review all the available documents and can be somewhat subjective based on the experience of the reviewer. Arcadis recognized this as an opportunity to apply advanced machine learning technologies with both image recognition and artificial intelligence to improve the accuracy and response time for the development of a technical approach and costing through automation. This method can also be applied to other areas in the environmental industry with similar document review requirements like due diligence, mergers and acquisitions, and portfolio assessments.

The evaluation of documents prior to automation approach was subject to person's expertise, detailed searches of documents was required, multitude of documents had to be referred, maintaining references for extracted information was tedious, information retrieval was prone to manual errors.

This was a time-consuming activity requiring an average of 20 hours for reviewing documentation and preparing one site summary. The objective of automating the process was to reduce time and effort in document searches, extract most relevant information and ensure standardized site summary generation.

- A knowledge base is created that consists of words, phrases, and sentences that help to answer the key questions in a Site Summary, and to recognize them in their context to replicate the human intelligence. This knowledge base is used to train the NLP model and extract the relevant paragraphs and phrases from the historical documents.
- Keywords and phrases are fed into the knowledge base and its embeddings hit the corpus each time when specific site information is available.
- Using a Deep Learning language architecture (custom word/sentence embeddings using Elmo/BERT) the relevant paragraphs are extracted using the semantic search query mechanism and it is highlighted in the results file.
- It is then passed on to an Entity Recognizer and a QnA module so that the exact answer for a query is retrieved

Two models cater to the overall extraction of the pertinent information: 1) the classification network which segregates all the unwanted information about a site and 2) the embeddings model which extracts the matched results. With the two models, the relevant information is extracted from the historical documents, automatically compiled in a list with associated references, and is used by the technical teams to develop the remedial strategy. By applying NLP to this process, it increases the consistency, reproducibility of the assessment, and results in a 90% reduction of the level of effort.

PERCEIVE

One of the main goals of AI applications is to replace in large part human tasks through automation. Although the process requires considerable upfront investments and domain knowledge, the technology can generate many benefits. One of the applications of AI with the most potential is computer vision, through which different objects can be identified, located, and classified. Normal inspection is a process that is both costly and time-consuming. The information can then be processed in real-time and reports are automatically generated at a faster rate, and with more accuracy as compared to manual and visual inspections carried out by humans. The reports, containing "visual data", such as images, or videos, or point clouds, enable the asset owner to make fact-based decisions regarding the state of their assets, the performance, and possible future damages.

Although this technology has recently received a lot of attention, the field of computer vision is not new. Indeed, deep learning neural networks and algorithms, which form the basis for the technology, have been studied since at least the early 50s by minds such as Alan Turing. The recent focus on this field is mostly linked to new advancements such as more powerful computers, new algorithmic models, and larger training datasets. Within the field of computer vision, object recognition and semantic segmentation are two areas that witnessed some of the most significant improvements in their performance. Both capabilities allow computers to behave appropriately for the context in which they operate, for example by searching multiple objects within an image or objects they interact with. Moreover, recent developments also allowed for the achievement of high performance with relatively small training sets, hence enabling the development of simpler models and less computing power or cloud computing costs.

Roland Dijkhuizen
Amersfoort, The Netherlands

As Lead Data Scientist & Product Owner Computer Vision, Roland has been with Arcadis for 6 years. His focus is Data analytics, Machine learning/AI and Deep learning within the Infrastructure, Oil & Gas and Ecology sectors. Roland believes that currently, we are witnessing the momentum of AI, and that it's the right time to act.

At its core, computer vision technology uses deep neural networks (a subset of machine learning), and deep learning. In simple terms, neural networks are AI systems based on simulating connected "neural units" and on modelling the way that neurons interact and communicate with one another within the human brain to make sense of external stimuli. This technique is referred to by many as deep learning since neural networks are composed of many "deep" and "hidden" layers that simulate interconnected neurons. Although these models require a large number of labeled training datasets and a considerable amount of computing power, they are particularly powerful at extracting patterns from complex, multidimensional data such as images, videos, audio, or speech. Thus, the technology is very scalable and the model, once trained, can be applied to different similar situations. As mentioned, computer vision technology is very powerful at extracting complex information from visual data. Moreover, these AI models are also capable of tackling highly nonlinear practical problems and can undertake predictions and generalizations at high speed. Because of this, computer vision significantly improves visual information processing, which is still performed manually by many of the key players in the AEC industry. A manual inspection usually entails a large range of activities, from asset inspection, large-scale object identification, to predictive maintenance. These activities are very time-consuming and repetitive, and they require an on-site presence. Ultimately, they are very costly, amounting to billions of dollars yearly. Furthermore, these activities are also highly prone to human errors, which drives up even more the costs.

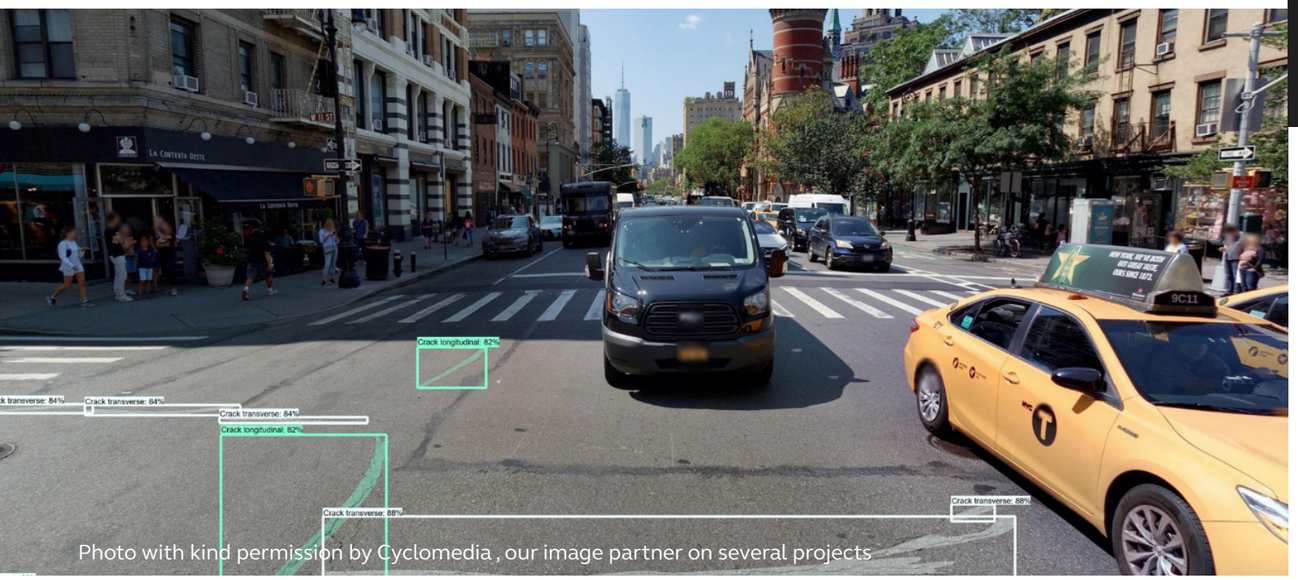
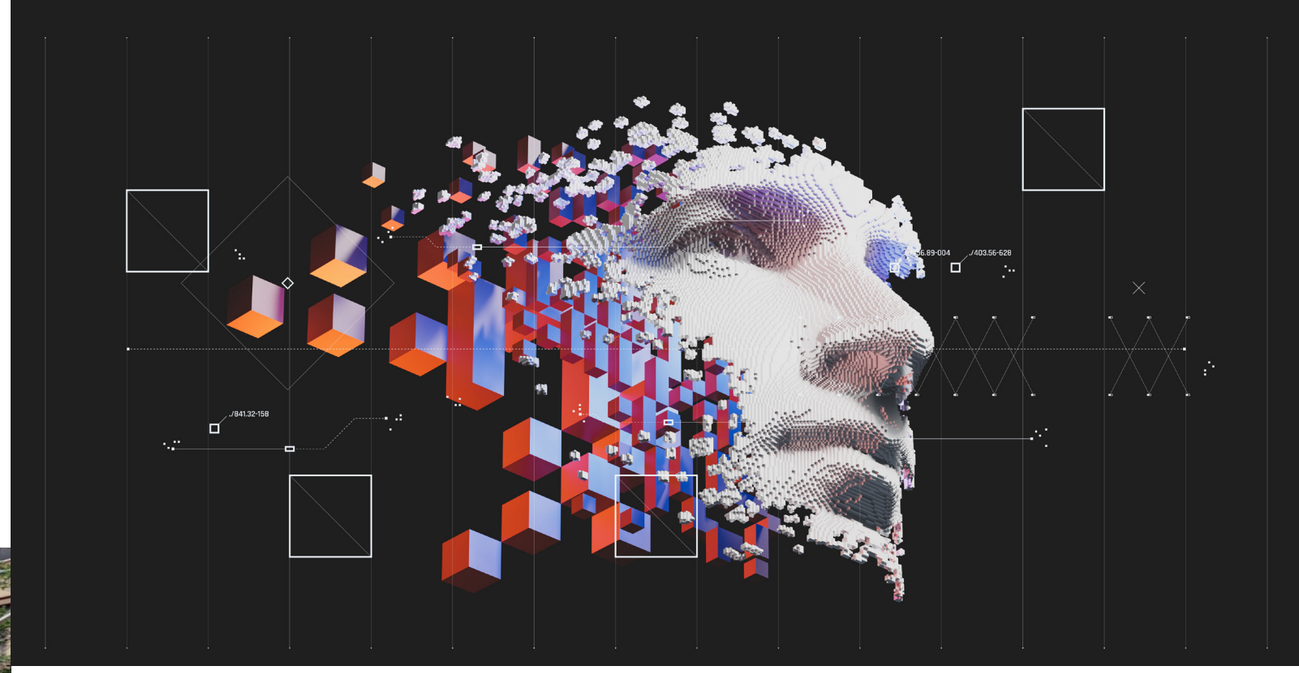


Photo with kind permission by Cyclomedia , our image partner on several projects

Computer vision detection models, instead, showcase an accuracy of upwards of 95%, and a processing speed which is faster than the human one: automated reports can be ready within a couple of minutes. The accuracy and speed of data processing are also reinforced using deep learning, which is capable of learning from past data while eliminating subjectivity and random information which might vary from inspection to inspection in traditional settings.

The case studies in which this technology is applicable are varied. For instance, the power of AI can be applied to asset assessment project, whereby it is possible to automatically detect the type of asset and their state by visual data gathered from images, videos, satellite, and aerial footage. In these situations, a training set is built leveraging experts' knowledge, which will label historical assessments and reports. The labelled information is then fed to the deep learning neural network, which will learn how to identify which defects to look for and their severity. The application of computer vision technology and thus significantly reduce the cost of asset maintenance by capturing more value from abundant visual data, by automating repetitive activities, and by increasing the processing quality of data.



Deep learning models can also be applied to detect changes and objects from point cloud (LiDAR), which is a collection of millions (if not billions) datapoints in a 3D space to represent objects in space. Although these datasets are too big to be analyzed by humans, the model is capable to quickly cluster and analyze a vast amount of data in order to detect, for instance, changes in rail signals, defects like rutting and equipment at high voltage stations. This is especially useful for monitoring high-risk objects with strict regulations, and for when accurate calculations are needed (for instance, to evaluate the severity of road defects). Finally, computer vision models can also be used for predictive maintenance. Deep learning algorithms have the capability of analyzing a very large amount of high dimensional data that can take preventive maintenance systems to a new level. Indeed, layering additional data, such as audio and image data, on top of existing ones, can enhance the predictive capability of the models, as they are capable to learn from a completer overview. By being able to detect possible future failures in an asset component, these models could significantly help reduce operating costs while improving production yield.

Ultimately, this is only the beginning of computer vision in the industry, and many more applications will arise. A crucial enabler of these innovations will be new sources of data. For instance, Virtual Reality and Augmented Reality tools will be able to collect more granular data, and smart high-performing household equipment will allow to collect more frequent information. These new sources of data, together with the visual data already owned by the company and with open source governmental data, will allow to significantly improve the models. In fact, it will be possible to train a simplified and more flexible model at an even faster rate. Moreover, the big inflow of visual data will support the integration between AI and BIM, through the creation of a digital twin of the asset. A digital twin, as explored in the IoT article, is a digital replication of a physical object. Asset management will be able to establish a proactive approach in consultancy: the analysis of the asset will allow to identify problems for the clients before they can happen.

Finally, as the range of applications of computer vision grows, the scalability of this technology requires new innovations in business models. Because of these characteristics and advantages, projects leveraging the power of AI models will have to follow different considerations, especially in terms of pricing and project management. For instance, if in traditional projects the scope of the assessment is calculated on time and size, this is not possible with AI-based projects. Indeed, training a model is less influenced by the two previously mentioned factors, but highly dependent on the quality and size of the training set. In this sense, the coding phase can be regarded as a fixed cost, and what defines the final budget is variables such as the type of model (object detection, point cloud segmentation, change detection), input source (camera, drone, satellite), or amount of classes to detect. Additional aspects to consider can also be the consistency in surroundings and input data, the number of objects per mile, the required performance and availability of a training set, etc. Ultimately, this technology has allowed the development of a new business model, whereby the costs are often determined by miles or the number of images. Because of the particularities of this technology, new innovations need to be evaluated not only according to technical criteria, such as the type of input data needed or the nature of the algorithm but also on crucial aspects such as the easiness to scale the solution to other projects as well, the specific domain knowledge required and the strong business case in general.

CASE STUDY

Road defect detection

Physical and manual inspection of road defects takes up a sizable amount of resources as well as labor time for public asset maintenance, specifically when irreversibly lost on inspections of roads that at the end turn out to have no defects. Thus, the goal was to minimize this time by building an algorithm that can find the defects and repairs, classifies the type as cracks and raveling, addresses the severity and calculates the sizes. Furthermore, the model was designed to be easy to use with a software module, both input (images or videos) and output (report), with a direct link to the clients' own management systems. As for visualization the induvial defects are shown in GIS and aggregated based on relevant methodologies such as ASTM and CROW up to 100-meter segments. Therefore, this development enables asset owners to analyze their road systems at a large scale and at the same time zooming in on specific locations to see individual defects and needed repairs.

The model was developed using a cloud-based solution to be sold as a SaaS (Software as a Service) product. First, imagery was collected by either an external company as Cyclomedia (API) or a GoPro. Then the training set was built on expert knowledge based on labelling of historical assessments and reports. A Deep Learning Neural Network learns based on this training set what are the objects such as road defects, repairs, road assets and other. The image recognition processes the input data for road defects and detects via image and immediately afterwards classifies the type of defect (e.g. transverse cracks, raveling, longitudinal cracks). Further, the severity is determined, size calculated and geographically positioned on a map. Then the output can be tailor made in every system by either API, XML that's applicable to every GIS environment or asset management tool and is linked to relevant road methodologies. Finally, the report is automatically generated and customized according to the client's need with the exact location of a defect, it's severity and past maintenance.

The use of computer vision has been proven to improve greatly the inspection of roads. That could be evident first from the fact that the accuracy of asset data being captured in the field, with the object detection model detecting all road defects (>95%) and classifying all road signs (>95%) correctly on both overview pictures and videos. Furthermore, computer vision improves efficiency by 50% compared to traditional digital inspection, and 80% compared to physical inspection. Most importantly, the technology can save asset owners significant costs at minimal up-front investments, whereby the simplest inspection can be immediately implemented on-site with a single GoPro, drone, or from existing satellite footages. Cost reduction is mainly based on the elimination of the need to physically sent teams into the field to collect asset location and type data. Additional to the efficiency improvement, 50% of the time allocated to maintenance was saved through automation of visual inspection. Also, by replacing inspectors on locations, the system is safer because no deposits were required, and drivers can stay in the car while the normal speed is driven. The technology saves a large number of labor hours in general, as well as increase safety at the workplace by minimizing on-site inspection.

crea.vision

One of the main challenges of AI applications is improving the way computers see and understand the world. Although a computer can detect images through cameras, the capability is not perfect, and traditional security cameras and their image quality represent an important barrier to fully utilizing computer vision technology. Most security cameras have a series of limitations such as range, field of view, spatial orientation, flexibility, and automation potential. For instance, in the case of facial recognition, there is a limited zone of recognition where the individual must be situated for the software to recognize it. Therefore, the camera architecture is inefficient for many computer visions purposes.

The start-up crea.vision aimed at solving this issue with the development of a sensor, called Panoramic Vision Sensor, which mimics the human vision and combines two types of vision: peripheral vision (responsible for detection), and front vision (responsible for detailed recognition at distance). The young British company was established with the mission of "enabling machines and computers to see the world better". With this mission in mind, the designed sensors maximize the application of computer vision and AI through their 360° visual field with real-time localization, both of which allowed for increased accuracy and applicability of the technology to a larger variety of automated activities. For instance, the solution can be used for smart buildings and digital twins, by analyzing how physical spaces are used in real-time, or for behavior analytics, to support decision making regarding the use of space. Additionally, the sensor can also be used for transportation analysis purposes such as bottleneck identification, traffic flow optimization, etc. Finally, the solution could also support in the automation of experiences such as the security or identification processes by using a biometric scan instead of card or ticket scans, thus leading to higher efficiency and a smoother operation.

Ultimately, the solution allows for an overall better performance thanks to the capability of detecting objects and individuals from a longer range with a much higher accuracy than usual solutions. Moreover, the sensor allows for real-time localization of objects based on coordinates of the subjects in a map which means movements can also be analyzed. The products therefore allow for a better and broader application of AI and computer vision technology to improve and automate processes to achieve better user experiences in many different settings.

KNOWLEDGE REPRESENTATION

As the commonly quoted phrase from Sir Francis Bacon goes, "knowledge itself is power". Living in an era of data abundancy, it is taken for granted that with information intuitively comes knowledge. However, that is not necessarily the case as organizations around the world struggle to make sense of their collected data, and values fail to be extracted. With the applications of AI, knowledge can be made more accessible to all those who benefit from it through two main highly interrelated channels of data management and data visualization.

Data Management

Data Management and AI are synergistic, in the manner that integrating AI in data management practices is necessary for building an effective underlying data and analytics platform, but the power of AI can only be truly realized with proper data management. Using AI capabilities, alongside with other tools used to achieve consistent access and delivery of data across the lifecycle, is necessary to meet the data consumption requirements of all applications and business processes. With data coming from multiple sources, AI can generate knowledge and insights that enable accurate and profound decision-making in business practices. In the case of the AEC industry – which is characterized by complex asset-intensive organizations, projects, programs, and portfolios, data management serves as an essential foundation in order to efficiently get access to the knowledge bundled in structured and unstructured data. In allowing for the discovery of knowledge, data management powers predictive and prescriptive actionable insights and many more successful advanced analytics initiatives and applications.

Chris Lambert
Birmingham, UK

Chris's area of interest is Information Management and the application of technology to digitalise and transform business processes. For 20 years he has been helping organisations to make informed decisions and create lasting impact. Chris has a particular passion for Through-life Engineering and Asset Management, showing how information and AI tools can generate strategic insight and drive business transformation in asset-rich environments.

To enable future AI initiatives upon these foundations, each data point must be collected and managed in line with an AI-focused strategy, which encompasses all the data lifecycle phases, from collection to processing of incoming master or metadata. AI allows firms to move away from rule-based data management policies, whereby rules for processing every eventuality depend on initial predictions made by a human. In the age of data, where data grows in unpredictable volume and scope, the AEC industry is dealing with the exponential growth of heterogenous data given by improvements in data collection technology enabled by commoditization of technologies such as IoT sensors. Using machine learning models, data management can shift towards goal-based policies whereby the program can be trained to do the "heavy lifting" work in processing data, detecting similarities and relationships, and overtime it can independently identify and create the appropriate methods to ensure that knowledge is safely and properly managed.

In this context, the priorities of the organizations will be to find the right balance between efficiency, data ownership, and data security. To cater to these new needs, an increasing number of software tools will provide segment migration methodologies, hybrid clouds, and cross-platform integrations which meet the needs of the data based on its criticality. This means that centralizing and managing data on a single source of truth will become much more cost-efficient. Moreover, it will be possible to build the architecture of your data systems right from the start, which will allow the organization to support future expansions and to develop best practices for data storage. The potential of good data management practices is visible in companies which were able to establish successful governance around their processes and which witnessed, consequently, sustainable business growth.

Overtime, categorization of data enables the development a data catalogue with an overarching data lineage and structure, and eventually it allows data to be united from silo structures towards a centralized data lake. This is valuable for enterprises and a digital project management office. A central data lake that is a "single version of the truth" has large implications on the standardization of processes, automation of activities, and better knowledge dissemination across an organization or within a large project. Asset intensive areas within the industry, such as brownfield restoration, water and wastewater services benefit from properly structured and governed data to retain a holistic base of knowledge with regards to ongoing projects. Especially BIM supported projects have great potential. AI-driven data management, such as the intelligent structuring and automatic categorizing and deduplicating of datapoints, supports the construction of a monolithic database at the center of business processes, that would not be possible without correctly handling the amount of data collected today, specifically with variations in collection methods and siloed organizational/project structures often found in the industry.

However, data management does not only concern itself with proper information storage, but also the effective extraction of robust and assured data and transforming it into actionable knowledge. From that comes the generation of valuable insights to support successful decision-making. AI-driven data management is at the foundation of discovering knowledge in the ever-growing data lakes by leveraging machine-learning-based methods to support in Big Data Analytics. For instance, data mining – which leverages machine learning, statistics, and pattern recognition – is an essential part of data management where an automatic or semi-automatic exploration and analysis of large data volumes can provide more and better insights that would otherwise be lost. Many areas within the industry benefit from such access to information and data that supports decision-making, planning, and performance reporting.

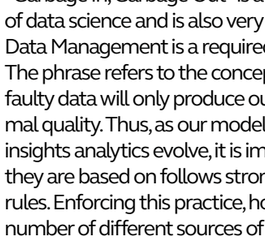
The future of data management and AI offers even more potential benefits as AI capabilities develop and get adopted on a larger scale. At the forefront of data governance, AI is providing solutions towards data privacy, security, all the while counterintuitively allowing for uniting isolated data sources and broader access. Initially proposed by Google in 2016, federated-learning is a machine learning technique that enables for the establishment of robust machine learning models without the need for centralized data-sharing, allows accessing information across multiple sources, all the while circumventing the increasingly regulated issues of data privacy, and increasing overall data security. Going beyond governance and data structure, Big Data Analytics will also grow in importance as information grows in volume and complexity with more automated and multidimensional collection methods with increasing use of technologies such as IoT and digital control. Additionally there are certain trends growing towards the servitization of assets, pioneered by Rolls Royce "power-by-the-hour" which continuously lease and maintain aero engines throughout the asset lifetime instead of simply providing the product. In exploration of such a business model, data will play even a larger role as many more static assets and products shift towards operation and maintenance business models.

Ultimately, value generation and knowledge access through Big Data Analytics will increase in importance and become an integral part of knowledge discovery to replace more traditional analytics as the industry pushes towards technologies that enable continuous and instantaneous 360 perspectives on asset conditions or project progress. With more access to comprehensive, high quality, and real-time information, AI-driven data management can enable better data-informed decision. This is applicable throughout all areas within the industry but particularly relevant for business advisory, operation and maintenance of assets, and program management. Finally, an AI-enabling foundation will bring about many further technologically advanced initiatives within the industry, allowing for better efficiency, decisions, and investments beyond what can be imagined as of currently.

Data Visualization

"Garbage In, Garbage Out" is a very popular concept in the area of data science and is also very used to support the idea that Data Management is a required function within the company. The phrase refers to the concept that models fed with poor or faulty data will only produce output with the same sub-optimal quality. Thus, as our models, management practices, and insights analytics evolve, it is imperative and vital that the data they are based on follows strong governance practices and rules. Enforcing this practice, however, is becoming harder as the number of different sources of data increases.

Nevertheless, innovations such as the cloud and data lakes have greatly supported the management process of all these new sources. Indeed, they allow for a gradual centralization of the data as well as for the empowerment of companies, which no longer are required to purchase or stand up their hardware services. Instead, they can collaborate with tech giants such as Amazon, Microsoft, Google, and others, to host information on centralized systems with ease of access and integration capabilities as well. This technology is witnessing a rapid increase: according to Gartner[6], over the past decade the size of the market for data-based management systems on could technology has grown up to ~$40b just in the US. Although a future where all our data is stored in the cloud is unlikely, there will come a point in which most of the data will be.

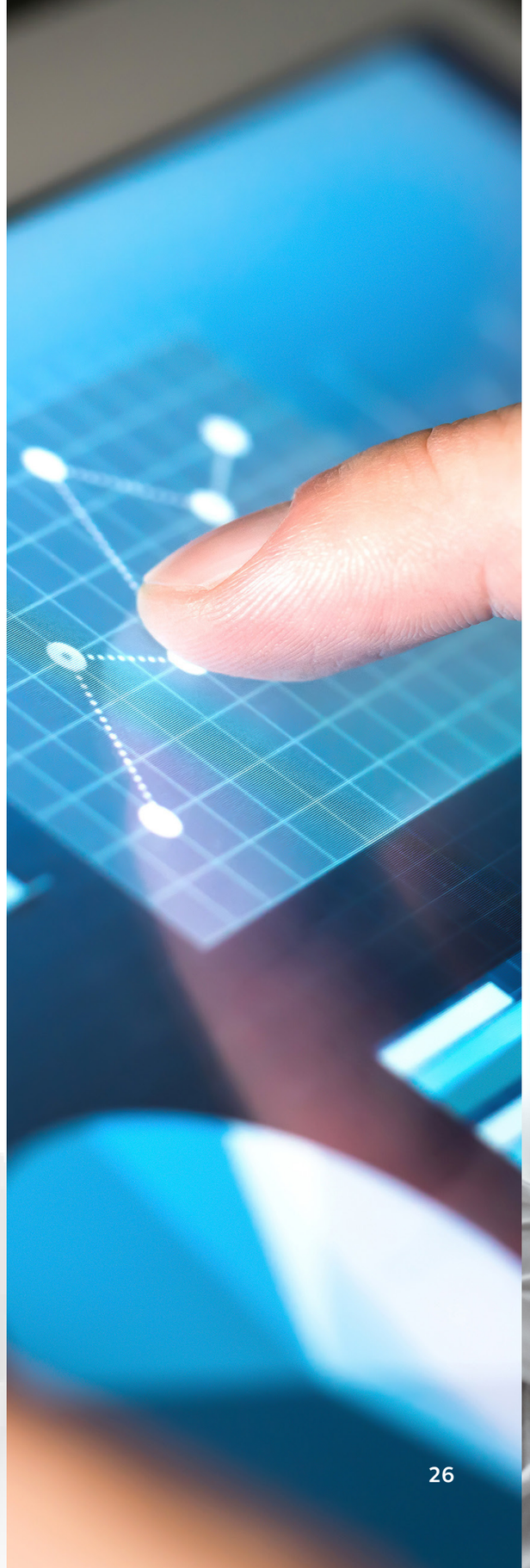


Abhinav Anandveeraraghavan

Washington DC, USA

After an MBA at William and Mary University, Abhinav has been working with Arcadis, in the realm of data and technology for the past 5 years. He has collaborated with clients across various sectors from Chocolate to Banking to understand the business requirement, identify pain points, define the need using a variety of consulting and design thinking toolkits. Implementing technology-agnostic solutions in the problem-solving process helped him bring the clients the "Aha" moments he loves to hear!

[6] Gartner. (2018). Gartner Forecasts Worldwide Public Cloud Revenue to Grow 17.3 Percent in 2019. Retrieved from https://www.gartner.com/en/newsroom/press-releases/2018-09-12-gartner-forecasts-worldwide-public-cloud-revenue-to-grow-17-percent-in-2019



In the future, as it becomes easier to store our information on the cloud and host operational information seamlessly, we will start to witness an era of platform disruption. Indeed, today we rely on APIs, custom code, or data extracts to achieve a single source of truth. The data management standardization trend will propel the need for cross-platform integration to use the data stored more easily and support data visualization and AI. With growing data by sources and contents, access to insights must be made possible for different audiences in order to realize actions and decisions needed. In this aspect, data visualization is highly important in ensuring communications between all stakeholders.

The same principles underlying data visualization can also be found in the alphabet. As the letters of the alphabet are arranged in different ways, they form sentences that convey different messages based on how they are communicated. In the same way, data visualization allows to combine data coming from different sources and which are in different forms, to create one single source of truth for the data. Therefore, storing the right information in the right format becomes critical to ensure the creation of intuitive and insightful analytics.

In the last years, there have been major evolutions in data visualization, thanks to the integration of AI in this domain. This enabled the development of interactive visual exploration of the data and empowered organizations to model and predict the consequences of operations or decisions. Therefore, it is now possible to use prescriptive analytics to understand the best path and improve strategic decisions. The integration of AI within data visualization is also enhancing operational processes. For instance, recent innovations allowed to integrate a Q&A tool powered by AI within many data visualization software.

The capability, which is often called visual analytics, can support a user even if they do not know the entirety of the dataset and do not know how to manually reach an insight. It is now possible for people to type a general question on the data, which will be then elaborated by the software to provide the answer to the question in visual form. Currently, this technology is already present in some tools, but will greatly improve soon. The tool will learn based on what you did or asked in the past and will be able to provide different options for a query. Moreover, it will also be able to suggest useful visual interpretation of the data without a specific query, based on the past needs and habits of the user. This capability is crucial in supporting data lakes initiatives, as not all areas in the organization have enough skills to know about different data sources and their particularities.

As the technology will continue to improve in the future, we will not only be able to visualize data but to replicate it in a virtual space, in order to come as close as possible to touching and feeling the data. Tech Giants are developing technologies that will be able to capture and act on data points that would have likely been missed with normal software tools. An example of this innovation is the use of virtual reality and augmented reality during the construction and inspection moments. By using such technologies, it will be possible to overlay the 3D model of the project (and digital information in general) on top of the existing construction, to check for improvements and possible mistakes. This will allow to make the overall process much simpler and reduce future costs caused by the need for fixing construction errors. Seeing in real-time how the project will look like once finished, and how the process is going, will be also incredibly useful to involve non-technical stakeholders within the process and keep them up to date with the development. Ultimately, thanks to the integration between AI and data visualization, the overall quality of the project and the asset will greatly improve.

CASE STUDY

Dynamic data management and digital reporting

Following a break in one of their dams, a client experienced several challenges in effectively monitoring and managing the consequences and the restoration process. Many of these challenges were linked to a need to develop data management: data was coming from several sources and needed constant monitoring and effective handling, which are crucial to have a clear overview of the situation. Moreover, the client needed digital tools and solutions which would make possible the interaction between multiple stakeholders and help manage the restoration project more systematically. Therefore, Arcadis was asked to intervene and support the company by developing an emergency action plan and a digital strategy which focused on dynamic data management and digital reporting.

Arcadis approached the challenge with a comprehensive digital strategy developed by the strategic environmental restoration team, which included the development of workflows for data collection, and the creation of a data model for non-chemical databases such construction, monitoring, and remediation systems. Advanced analytics tools like Python were used to improve the data monitoring and utilization capabilities, whereas scripts in VBA, Power Query and UiPath were developed to optimize time by automating processes such as data verification before their migration to the final database, and the real-time data collection. Arcadis' tool FieldNow was also implemented to automate and digitalize the data collection process and to create a consistent way of reporting, which would guarantee the quality assurance and quality control (QA/QC). Finally, throughout the project, several hundred dashboards were developed to support the client and allow them to have a clearer and more dynamic overview of the project. Several visualization tools were used, such as Power BI for data reports and dashboards, ArcGIS Online for location mapping and analysis, and Environmental Visualization System (EVS) for geologic modeling and other functions related to earth science.

The strategy implemented was able to strengthen the client's data utilization capabilities through the use of advanced analytics tools that supported data management and enhanced the interaction between all stakeholders. The tools also enabled the client to monitor closely the progresses made through visualization of data, hence making it easier to avoid delays. Moreover, the dynamic approach to data management increased data accuracy and consistency, enabling the client to develop a risk management and recovery plan. Ultimately, the client's satisfaction was great, and the overall project guaranteed the security of the information about water of the basin in the area.

LEARNING

Machine Learning

In the last years, many experts have compared artificial intelligence to electricity thanks to the profound impact that this innovation will have on industries and the society. In fact, just like the introduction of electricity revolutionized all industries, AI has the potential to greatly transform them as well.

Traditionally we have applied mathematics to study data from a sample and tried to infer conclusions about the population the sample derives from – the science of statistics. However, in today's information era, data is available in highly dimensional and unstructured manner, where the application of a traditional statistical model, which infers conclusions based on a series of assumptions on the nature of the data, has less utility. This is where machine learning models step in. Machine learning is the application of a mathematical algorithm normally aimed at prediction rather than inference. It makes few assumptions about the structure of the data it is given which makes it highly adaptable and able to learn from it. Even though it is based on mathematical models and statistics, it is effectively a field of computer science and falls under the umbrella of AI as it differs in its application. These models are divided into supervised or unsupervised. The first are trained on a labeled dataset which can effectively be used to evaluate its accuracy. The latter tries to blindly make sense of the data given fitting it into a pattern of its own.

AI technology can be generally defined as the capability of a computer of performing tasks and solving complex problems which would normally require human intelligence. Instead, as a subset of AI, Machine Learning is a technology that allows a computer to learn rules without explicit human programming. The technology enables the development of a new programming paradigm, whereby a computer can find patterns from the data provided instead of having data engineers dictate what patterns to be found. This capability enabled great advancements in the field of AI and led to amazing applications, which allow computers to see (computer vision), understand human language (Natural Language Processing), learn how to move (autonomous vehicles), etc. Within this industry, the ability of a computer to capture and process visual information, for instance, has gathered a lot of attention in the last years has been applied to several tasks, such as defect detection. Instead of using the human eye to inspect millions of images and make reports about the quality of an asset, for example a road, we can apply AI to inspect the images automatically. The algorithm used is a supervised one, meaning that it requires the input of training data whereby the target object (i.e. the defect) is labelled, that is identified. Subsequently, the algorithm will be able to detect patterns in the training data and to develop rules which will be applied to new images to identify the defect.

Ilinca Dinu

Bucharest, Romania

With a PhD in Civil Engineering and more than 10 years' experience in working and researching the industry, Ilinca is the lead to one of the Arcadis Digital Hubs in Romania. Her main expertise includes data management and engineering for infrastructure assets, environmental consultancy and reporting, data analytics and project management. In recent years Ilinca has focused on the development of data science with a main focus on large applicability of machine learning such as image recognition, predictive and anomaly detection, automation and dashboarding.

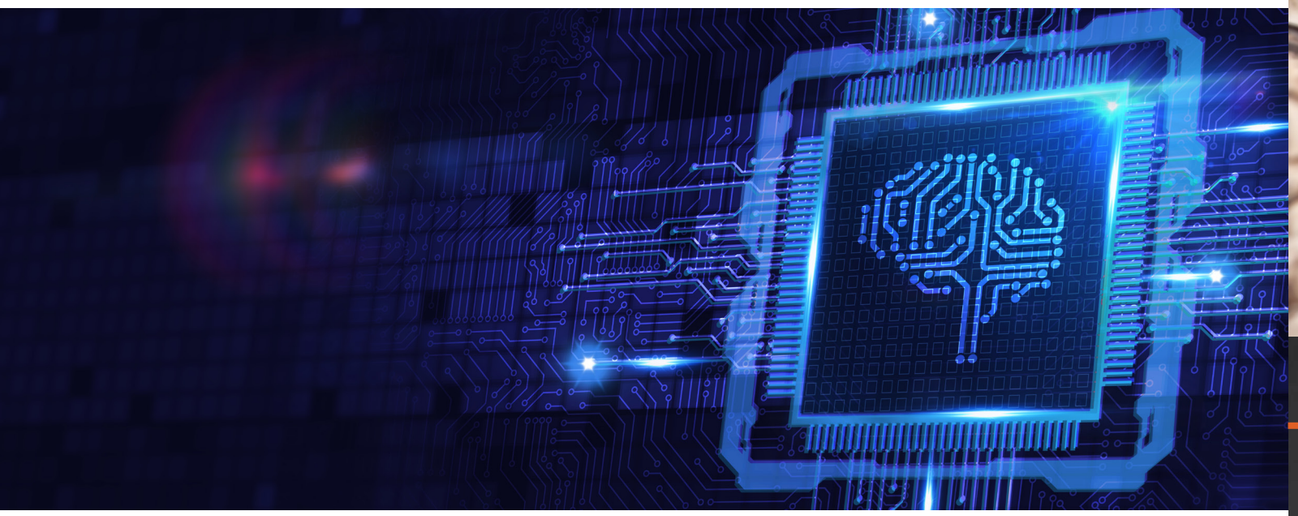
Emanuel Pintilii

Iasi, Romania

With a mixed background in economics and statistics, Emanuel has a passion and enthusiasm for AI and statistical modeling. He joined Arcadis in February 2018 where he continued to develop his expertise in deep learning for image recognition and machine learning in general.

Besides the application of machine learning to asset management, AI can be used in areas such as Building Information Modelling. The BIM process aggregates 3D models from different backgrounds and varied informational sources (architecture, engineering, mechanical, electrical, and plumbing) that are essential for a comprehensive view when designing physical assets. In this context, the challenge is to properly integrate all these 3D models or make sure there are no issues when combining them in a larger project, and therefore, AI can be used to quickly detect the potential clashes that may appear between these different models.

While the application of AI can serve for descriptive purposes, the inflection point starts when machine learning enables the power of prediction. Predictive analytics uses historical data along with statistical techniques to be able to predict what will happen in the future in a more reliable and accurate way than other previous tools or human intuition. This capability will enable improvement in almost all areas of asset management, such as monitoring, quality assurance, and health and safety. Generally, the machine can learn how the asset works usually and is able to detect possible future changes based on anomalies in the performance. Moreover, the model can also be used for the optimization of energy consumption and increased production by predicting the peaks of use for the asset. Overall, predicting the performance of an asset can greatly benefit the asset management process, by optimizing the consumption costs and improving the overall performance of the asset.



In the future, predictive analytics will continue to revolutionize the traditional processes of the AEC industry such as maintenance task, where predictive analytics is being applied to predict when failures to assets or machines will happen. Although the capability is already present in some companies, in the future, as more and more data are collected, the models will be able to drastically improve their ability to detect possible anomalies. By implementing such a technique, businesses will be able to make the whole process much more efficient and reliable as compared to a preventive maintenance approach or one that is based on the expected operational life or an asset. With this new approach, an asset or a machine is fixed or replaced according to its current performance and state, and therefore costs will be allocated much more efficiently than previously, when some machines would be replaced too soon or only once they have broken down, which also caused additional costs due to interruptions to the workflow. Moreover, the quality of the performance of predictive maintenance is deeply linked to the quality and quantity of data provided to the model. Because of this, the potential of predictive maintenance can be further improved by leveraging industrial IoT capabilities, through which businesses can have a constant inflow of real-time data on the asset and its performance. The increased attention given to big data will also significantly improve the capability of machine learning models to predict future failures or the performance of an asset, and at the same time will increase the importance of these models, given that humans would not be able to process such a large amount of information. In return, machine learning will become an essential tool to process big data, as it supports unsupervised or semi-supervised analytics such as data mining, enabling effective insights discovery that would be impossible manually.

In the upcoming years, the business is expected to be disrupted by many technologies and innovations, among which predictive analytics and maintenance are two of them. However, companies will be able to truly benefit from these technologies and be considered an AI company only if they will follow a holistic approach to data analytics. This includes making strategic decisions regarding data acquisition, developing an infrastructure that could be easily used to store and analyze data, make deployments to the models, and reuse them. Without this holistic approach and infrastructure, it will be hard to keep up to date with new trends and needs of clients and become an AI company.

CASE STUDY

Predictive maintenance of switch failures

The inspection of rail switches and detection of failures is a crucial aspect of the management of rail assets, as the failure of any of them is not only costly but also disruptive for the whole system. Asset Rail's challenge consisted of creating a model that would be able to predict these instances accurately, even if the historical data included a very small number of switches' failures.

To solve the problem, Arcadis developed a predictive model that could predict switch failures based on measuring electrical currents. Using a machine learning algorithm that was first trained on data of electrical currents of ten switches gathered before 2016. Its predictive ability was then tested on data from 2017. Further a pilot test was conducted that covered ten railway switches using 8 years of data. At last Arcadis optimized the model by developing an automated solution that would shift according to the season, as the temperature is a significant aspect influencing the outcome.

The implementation of the model greatly improved the maintenance and failure detection process. In fact, it can predict 40% of the failures with an accuracy of more than 20%, a good result considering the difficulty in capturing the information needed. Moreover, the model, which takes many variables into account in its predictions, is both similar to human performance and very clear to understand at the same time. This allows the client, which has access to data visualizations, to have a clear overview and understanding of the predictions made by the algorithm. More importantly, this model allows tackling more accurately switches which have a high probability of failing, hence reducing maintenance costs and making the process faster and more efficient.

CASE STUDY

Predictive pump failures

In the coal seam gas industry, progressive cavity pumps (PCPs) are commonly used as a gas extraction method. Operators of these pumps will typically deploy thousands of these across their well network in the region, and like any intensive mechanical pump system they are subject to failures caused by general wear and tear, blockages, or unforeseen circumstances. These failures individually are quite costly to the operators, not only for the capital cost to makeover the well pump, but also due to the non-production of gas created by the down time.

Arcadis approached such an operator in Australia who is a key client of the Australian business. Arcadis was looking to demonstrate our data analytics capability and entered discussions with the operator to understand some of their current challenges where a solution may lie in data they have already collected.

It was identified that the PCPs failures were common and costly enough to have significant business impacts and could be avoidable if enough early warning was given to undertake some preventative maintenance interventions. More importantly the client had a very large amount of data available on the pumps' performance, as every pump had sensors that collected across 15 different performance indicators every minute of every day dating back 5 years, including failure modes. Multiply this across thousands of pumps, it was too much data for the project engineers to interpret in real time and get a sense if the pumps behavior was within normal range.
For a proof of concept, Arcadis took a sample set of three years' worth of data for 42 wells located in a similar region. Four different types of machine learning models were built and tested to understand the normal pump behavior and flag when anomalies occurred outside these bounds. It was deemed that an isolation forest model provided the most accurate results, and this was further refined through feature engineering to reduce the number of false positives.

Once refined it was observed that the model was identifying regular anomalous 2 weeks in advance of a failure. These early indicators give the client sufficient time warning to investigate the well and undertake an intervention to significantly reduce the failure risk.

The next phase will see Arcadis build a prediction model to categorize which anomalous indicators will likely lead to a failure, and integrate into the operators streaming systems, so that real time analysis can be made on the pumps behavior.

When implemented the operator will see both a significant reduction in the number of failures, meaning less capital cost in making over, and a reduction in the production downtime, and therefore increased revenue.

Robotic Process Automation

Related to the concepts of machine learning, within the digital transformation in act within the Architecture, Engineering, and Construction industry, Robotic Process Automation (RPA) is perhaps the technology capturing the most interest and investments and it is amongst the ones which will go through a drastic transformation in the upcoming year thanks to an integration with Artificial Intelligence.

RPA, at its core, is a technology that aims at automating workflows and tasks which are very labor-intensive and are characterized by a low number of exceptions and consistent rules. This is done using one or multiple scripts called bots, which can perform several actions when triggered by specific external events. In many cases, the bots themselves are not "smart", as they do not own the capability of learning from data. However, it is possible to integrate machine learning models to the technology, to handle processes that are more complex and that vary with every transaction. A crucial enabler of this development is the Optical Character Recognition (OCR) technology integrated within a robot. The capability allows a bot to extract information from text, images, and documents by converting typed or handwritten text into machine-encoded text. When integrated with machine learning, this technology can streamline existing processes by capturing and process unstructured and semi-structured documents and data.

Anirban Chaudhury
Bangalore, India

With an MBA specialized in Finance, Anirban has been with Arcadis for 8+ years and has had several assignments in the past years ranging from Project Accounts, Business Development Support, Cost Management system implementations and Business Intelligence. In his current role, Anirban leads the Digital Shared Service team at Bangalore, in the Global Excellence Center India and engages in managing a team of Data Scientists & RPA specialists.

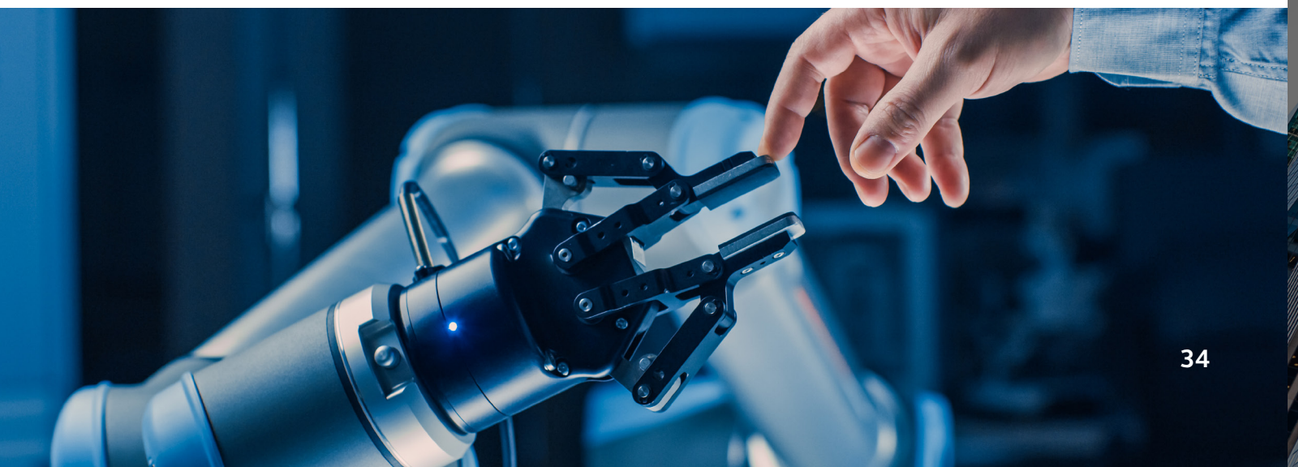
Such type of data is very common in industries that heavily depend on paperwork, documentation, and drawings, such as the AEC Industry. This is one of the main reasons for which this technology has gathered much attention from many businesses. Indeed, RPA can have large impacts on the profitability of a business which is still very labor-intensive and that operates with tight margins. The technology, which involves low up-front investments, is able to generate significant changes within the business processes very quickly: the technology is able to automate up to 80% of labor hours and leads to a drastic reduction of costs and time spent on processes. This leads then to a significant gain in productivity and ultimately of profitability. Moreover, the quality of the work is higher, due to reduced errors which are very commonly made by employees and a higher degree of compliance. Finally, by automating repetitive and time-consuming tasks, employees can focus on value-adding tasks, hence improving the overall quality of the business and the satisfaction of the workforce.

The possible RPA solutions which can be introduced to achieve such results are varied. Indeed, robots can be classified according to the level of supervision needed by humans: attended bots are capable of automating processes under the active supervision of employees, whereas unattended bots can work in the background of a computer without any necessary input from humans. Both solutions are relatively simple to implement and in the majority of the cases do not require specific programming skills thanks to the low-code interface of many of the solutions present in the market that allow to personalize the workflow and integrate automation with other capabilities such as OCR and Machine Learning. However, human action is still required throughout the development process since people are usually responsible for identifying possible processes to be automated and for developing the bot itself. Moreover, a certain level of monitoring is always required to ensure that all bots are running correctly. The integration of RPA with Artificial Intelligence will be able to automate even parts of this process by generating "smart" robots that can identity and learn processes by themselves.

Currently, several companies are offering RPA solutions with an AI integration, but it is expected that in the future this integration will become the norm and will be applied by the majority of the key players in the AEC industry. This will significantly impact every aspect of the RPA process. For instance, some solutions already provide the opportunity of using bots or AI technology to identify which tasks within the business process could be automated with the largest return of investment. This is done by consistently analyzing the workflows, and by identifying repeated and manual processes. This will help leaders in prioritizing the efforts as well as having an objective overview of the business opportunities.

Furthermore, AI will significantly impact the development of the bots themselves. As mentioned, the creation of a bot, either on a low-code interface or through programming, requires the intervention of humans. In the future, more and more companies will be able to apply AI to automate this process as well. AI models will be able to gather information from the process mining steps while eliminating noise such as random actions that do not belong to a workstream. Eventually, the model will develop a script capable to automate the process, and in the future, as the model gathers more and more information, it is expected that it will be able to suggest improvements to the workflow itself. Although this capability is already present in some companies in the industry, right now the process still requires a certain degree of human control and validation. However, as this technology improves, in the next years this capability will become more common.

AI will also be able to be integrated with the script in order to create "smart" bots that will be able to deal with complex and unstructured processes by leveraging technologies such as computer vision, natural language processing, and machine learning. Ultimately, it will be possible to achieve cognitive automation, which will enable the processing of highly unstructured data, such as images, interactions with consumers, etc. The OCR technology, for instance, is one of the capabilities which enable cognitive automation. Through this technology, it will be possible to automate not only repetitive and manual tasks, but also those key strategic processes which require a high degree of cognitive effort such as extracting relevant information from meetings. This will benefit several areas such as cost and commercial management, site and environmental restoration, and project management, and will benefit the client as well through more valuable and effective solutions. Ultimately, the integration of RPA with AI and other technologies and platforms will lead to the development of Hyperautomation, through which it will be possible to automate a large part of the enterprise and the most important processes.



CASE STUDY

Project monitoring for banking client

In a global account with an international financial institution, Arcadis was faced with a large and looming global audit of the delivered works to check for compliance with the Standard Operating Procedures. The existing contractual obligation dictated a self-audit of 10% of projects within each country which was a time-consuming activity and tasking a team to complete this action would burn a huge number of man hours.

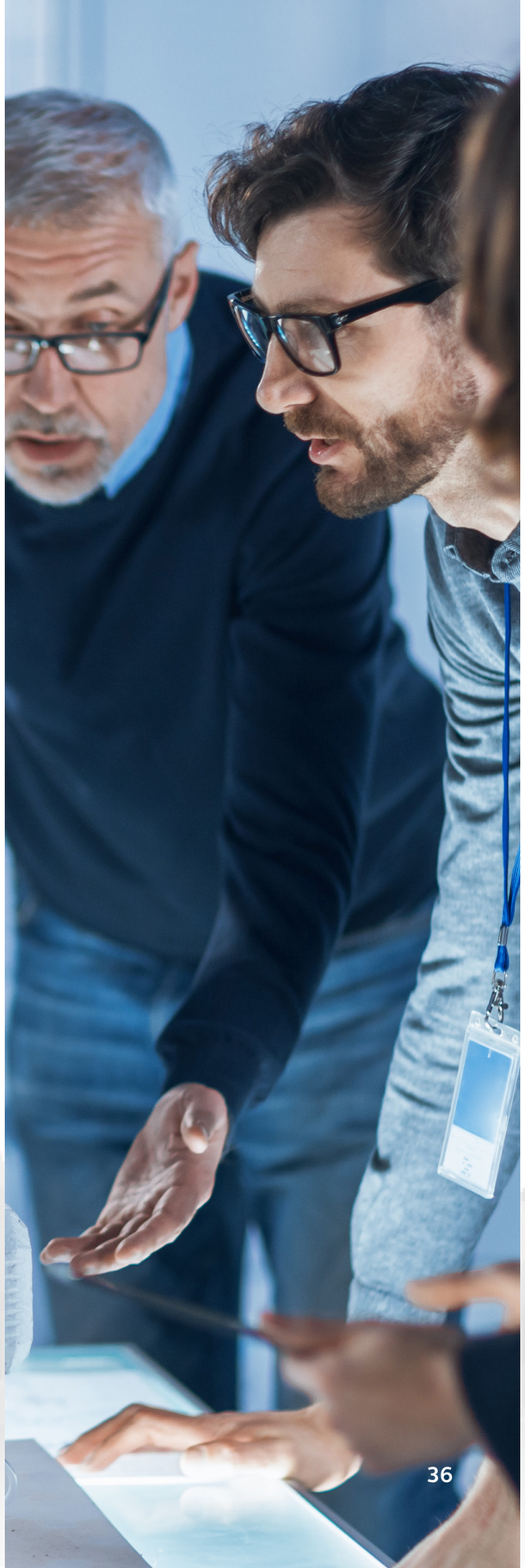
Arcadis engaged with a third-party consultancy firm to workshop a possible solution, resulting in the definition and design of an automated audit process. The GEC team built an automation through RPA technology which enabled a robot to assess projects in a defined list for their compliance against several criteria. Testing was completed in conjunction with the third-party with deployment of the automated solution driven through a virtual machine using orchestrator software.

As an outcome of the RPA technology applied to solve this challenge the time needed to complete an audit was reduced by four times and the number of human errors saw a significant decrease. Those reductions were also the reason for the improved employees' efficiency as now there is more time to perform higher value-added activities. Consequently, a higher employee's retention was achieved due the reduction in the number of repetitive and monotonous tasks. At last the price of the audit was decreased as after the development of the robot the only fixed cost is that of the virtual machine.

DECISION-MAKING

Many asset-rich organizations are now at a critical point caused by challenges related to their infrastructures: the assets are aging rapidly, and regulatory pressures and budgetary constraints are forcing these companies to think and act differently in order to generate and retain value out of their assets.

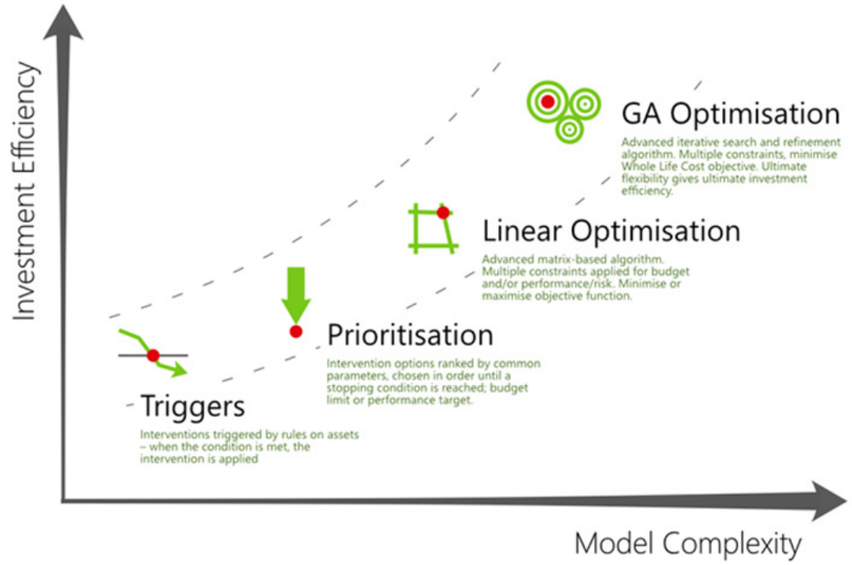
Data Analytics can help meet these challenges, as it provides crucial help in balancing risk and costs, optimizing asset performance, predicting future changes, and satisfying different requirements. These solutions, however, only deliver value when the insights generated lead to a different set of decisions being made when compared to a non-data-led approach. Moreover, making better decisions requires a clear understanding of aspects such as how the decision impacts organizational KPIs, and what is the relative value or trade-off between those KPIs. Furthermore, considerations regarding the current level of performance of the assets and how it will change over time due to age or changes in usage, operating environment, or demand, must be made. Finally, important organizational constraints such as the annual budget, the resource delivery capability, or the regulatory and political commitments influence the decision-making process as well, adding to the complexity of decision-making, and further complicating the task for human decision-makers.



Daniel Scott
Sheffield, UK

Dan is a highly motivated senior manager with over 10 years' experience of strategic asset management within the transport sector and over 8 years of experience in advanced analytics, data science and applied decision theory. He is a member of Institute of Asset Management with a proven track record of delivering transformational digital solutions across a range of sectors to deliver significant business benefits and develop robust long-term plans.

AI and advanced analytic applications can greatly support the decision-making process by accounting for these factors and restrictions. In fact, advanced decision optimization algorithms can search through the entire decision space of potential planned actions that could be carried out within the real-world constraints to choose the optimal option. The models vary based on its complexity and investment efficiency (as can be seen from the graph), but the majority of them, no matter the level of complexity of the asset and the restrictions, can identify a granular plan of actions which provides the mathematically best possible outcome against an organization's overall objectives. For instance, Genetic Algorithm (GA) optimization is an advanced algorithm that carries on iterative research by emulating natural processes of natural selection. In each iteration, the best solution or candidate action is selected based on its characteristics, to identify the optimal choice of action amongst many.



These optimization algorithms can be even more accurate once paired with advanced asset models, which can predict the performance of assets. An example application is the incorporation of different parameters and optimizing model into a decision-making platform that is easily accessible to all, like that of the Enterprise Decision Analytics (EDA) platform, which can support the process by allowing to develop and implement models tailored to specific assets and needs. The tool, developed by Arcadis GEN (previously known as SEAMS), is an integrated platform for asset analytics that features different building blocks for asset, portfolio, and financial modelling. Each building block can be individually configurated to design a platform that is tailored to the needs of the organization. The platform has been deployed in many different business sectors, such as water, electricity, rail and road networks, schools, and hospitals, and delivers a state-of-the-art strategic asset management decision support. Within these sectors, the platform has been used to represent a broad range of different asset types utilizing many different modelling methods, including high complex asset risk trees, advanced AI predictive models, Markov chain state transition models, and deterministic deterioration based on linear regression trained rulesets.

The capability of EDA to represent such a broad range of different asset types is enabled by its bottom-up modular design and open expression structure which enables any asset whose behavior can be described mathematically to be simulated within the platform. Furthermore, the modular nature also allows for the representation of the complexity of certain assets in a simpler form, through chains of modules which form an "Asset Analytics Pipeline" that accurately represents the behavior of that asset in the real world.

Additionally, the platform also enables the aggregation of results and asset groups themselves based on organizational or regional levels. Ultimately, the tool offers the opportunity for both experienced asset professionals and casual users to leverage the potential of these models and make the best possible decisions.

While this technology was developed within the strategic management environment with a focus on developing optimized long term investment plans, it has increasingly been applied more diversely within organizations to optimize tactical decisions (such as the identification of assets in need of maintenance), near real-time decisions (like those regarding predicted changes in demand in the near future), and operational decisions (relating, for instance, to the deployment of the workforce).

The expansion of the application of these sorts of technologies across organizations will continue in the future and will become more and more accurate as the models and algorithms deployed are optimized. Ultimately, it will be possible to link the long-term strategic investment decisions to real-time asset condition information and near-term operational and maintenance decision making. This will provide a "whole organization" optimization capability which will deliver significant efficiencies and improved organizational outcomes. AI will work as the primary processor of big data and will be able to generate a pool of optimal courses of action, which will be then evaluated by the team to reach a decision. Truly reaching for the data-led revolution to management, the interaction between human judgement and intuition and AI will greatly improve the decision-making process. AI will enable data-informed guidance in combination with managerial intuitions to reach a new future where data can maximize the efficiency of the day-to-day decisions as well as strategic ones in the long term.

CASE STUDY

Integrated Transport System Operator (ITSO)

One of the biggest Integrated Transport System Operators in California, USA, part of the public transportation system is facing the challenge of managing their numerous assets. The elevated and subway system connects San Francisco to Oakland through 48 different stations along 6 routes and is approximately 180 km long. Additionally, ITSO is one of the busiest heavy rail rapid transit system in the US, which poses the challenge of being able to renew different assets of the system at the right time. Because of this, an optimization model capable of predicting such necessity was needed.

Using the Enterprise Decision Analytics (EDA) technology, Arcadis GEN built a model capable of predicting the changing conditions of every asset on the ITSO network, from the rolling stock and track assets to the staff vehicles and computer terminals. Further, we integrated optimization techniques within the model to be able to identify the optimal mix of asset renewals, hence delivering the best overall reduction in network risk while complying with the highly complex funding rules imposed on ITSO. Conclusively, the implementation of the network renewal optimization model and the EDA technology greatly improved the performance of the network while also adapting to the highly complex funding eligibility rules that apply to ITSO assets. Moreover, the developed model can also account for the impact of the introduction of future new assets, such as a new fleet of trains and CBTC signaling system, and the associated disposal of legacy assets.

CASE STUDY

Dunea

As one of the leaders in the water industry in The Netherlands, Dunea's challenge was to maintain the competitive advantage gained in the asset management decision area. The integration of the already existing processes with data analytics was identified as a crucial point to implement to keep and improve the status quo.

Arcadis GEN's approach to the challenge was to use the Enterprise Decision Analytics (EDA) technology and consultancy team as a key part of the project solution. An initial pilot project was created in 2011 to advise the client on how to improve asset investment decisions to achieve desired performance and risk outcomes. Further a corporate investment strategy and a tactical plan were developed for single operating regions deriving from the pilot project results. Finally, we managed to effectively implement the methodology throughout the entire company and across all regions. By implementing the strategy developed by Arcadis GEN, the client was able to achieve a cost saving of approximately two million Euro on their annual budget, an amount which is equivalent to more than 17+% of CAPEX for distribution mains. This was achieved by better targeting investments, especially for decisions related to replacements in the piping network. Furthermore, the quality of the performance of mains greatly improved following the replacement investment strategy. The number of customer interruptions (OLM) consolidated, whereas the system experiences a reduced number of bursts, with the consequent reduction in OPEX (reactive repair costs).

AUGMENTED CREATIVITY

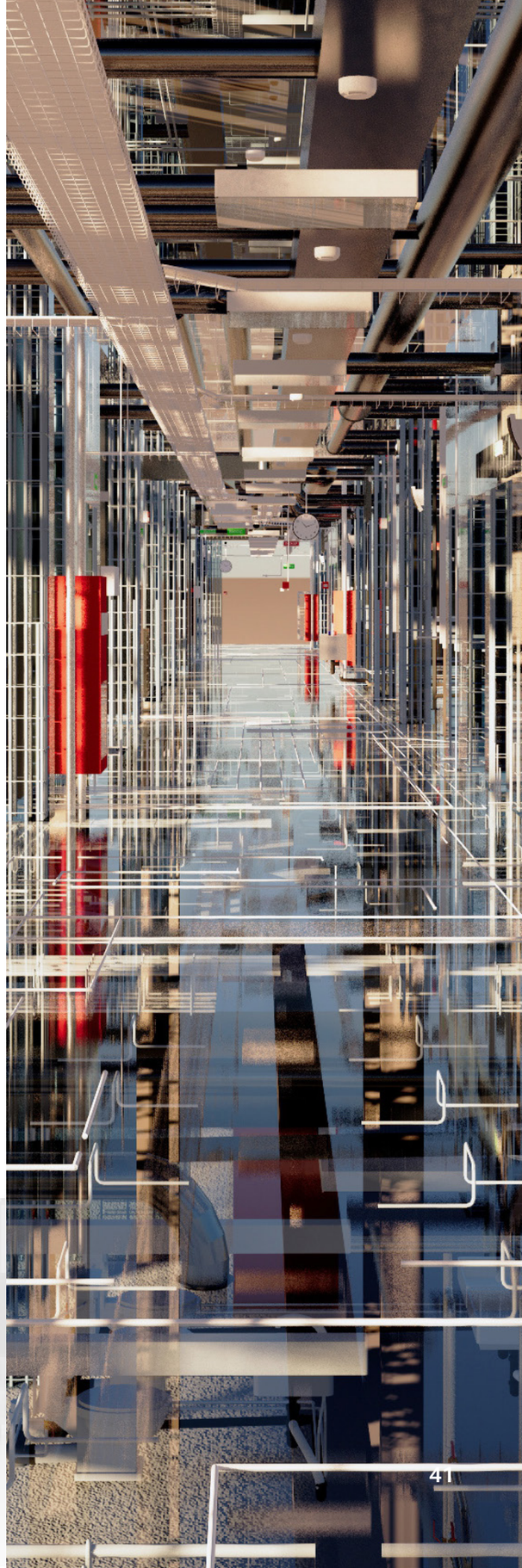
Design Automation, from a Design & Engineering perspective, is composed of three areas that developed in unison, allowing for innovations and adding value to design solutions.

The first area, parametric design, was first introduced in the AEC industry over two decades ago, and several aspects of this technology are integrated nowadays into design production solutions and BIM technologies such as Autodesk Revit. Parametric design is a rule-based process relying on algorithm thinking, meaning that a design change made on a BIM tool is automatically associated with changes to other related aspects. For instance, moving a wall in a plan view for a building project will lead to an updated overview of the square meter size of the room and to a stretch or shrinking of the adjacent walls.

Computational design builds on parametric design and can support a team by building a parametric relationship amongst technologies and accelerating output. In other words, it allows not only to automatically replicate a task but to optimize the outcome choice based on specific rules. For instance, in infrastructure projects, a set of scripts is often run in a parametric model to optimize rail track sizes, distance, performance, and costs. Finally, generative design leverages machine learning to further accelerate the process of computational design by producing multiple design iterations following pre-set design requirements. The set of options can be then evaluated by the designer, who can choose the best outcome for a client, based on past decisions. For instance, when undertaking a structural analysis of a steel truss for a type of roof structure, generative design would be useful in answering questions related to the specific length needed to reach the best outcome, based on past data and the current scenario requirements by allowing for simultaneous evaluations of multiple alternatives.

Andrew Victory
London, UK

Andrew Victory is the Global Digital Transformation Lead for Design & Engineering. Andrew has over 21 years of professional experience, having worked in Landscape Architecture, Commercial Architecture, and the Design and Engineering field. He is currently based in Arcadis's London office, though works in a global role within the global solutions leader's team with a focus on executing the corporate 1-3-year vision



All three aspects of design automation build on top of each other and open the opportunity of exploring different design options available to both the designer and the client. Indeed, parametric design (already well integrated into the AEC industry), is able to improve and accelerate certain tasks through automation, and to flag or automatically adapt other specific characteristics of the built asset after a design change. Whilst providing a solid foundation, the technology, however, still relies on the designer to optimize the outcome. Instead, computational, and generative design are able to indirectly support and replicate the imagination process of a designer, by producing a novel outcome without direct human interactions. Starting from minimum requirements and boundaries set by the designer, the technology is able to provide new optimal designs, and challenge status quo assumptions regarding the quality of human choices.

The AEC industry, however, needs to be understood as having a very broad spectrum, with projects in infrastructure (rail, highways, bridges), building (residential, retail), water, and environment. All these areas are characterized by very different restrictions and requirements, and therefore computational and generative solutions must be applied in different ways and taking into considerations these factors. Overall, the design process benefit greatly by having a computer that can incorporate all complex information to allow the imagination process to take place without being hindered by considerations of all constraints. Moreover, the industry is currently experiencing a large acceleration around these technology applications, with different sectors and projects proceeding at different paces.

Augmented Reality model elements appear draped over view of reality (in this case in different colors)

Overall, the development of such technologies within the industry is advancing and improving decision making. For example, it is possible to involve supply chain within the early concept development stages of the project, rather than in the prototyping phase, where adjustments to the construction would be difficult. Furthermore, a lot of decision making has traditionally relied on exchanges of data between different design disciplines such as architecture, structural engineering, mechanical engineering, and cost and commercial management, for the information to be reviewed individually. However, in the early future, it will be possible to integrate this information and to incorporate it into decision making, leveraging the use of predefined rule-based solutions that include a lot of specialty-based know-how. This information will be then taken into consideration by the technology as a baseline for initial design solutions.

Not only for the technologies support the designers, the adoption of computational and generative design also offers the opportunity to clients to engage with the creation at different stages of their AEC asset, through faster and consolidated sets, structured around rules. Ultimately, some clients might also be able to undertake aspects of the design exploration and decision making themselves, while the AEC designers would provide a supporting and guiding role throughout the design decision-making stages. Nevertheless, it is noteworthy to mention that this option is not optimal for all clients and projects.
Furthermore, clients will also be catalysts for change and push the boundaries of what can be achieved in certain areas of the construction process. Indeed, emerging advancements in our industry, such as industrial 3D printing and advanced materials that explore biological or nanotechnology, have not been taken into consideration by computational and generative design technologies. However, it is expected that these factors will be incorporated into the further development of the creative technologies. In a near horizon, it will be possible to help clients in developing a well-structured and predictable solution and, at the same time, to push the boundaries of the norm in the design process and deliver innovative solutions.

CASE STUDY

Agilicity

The imagination process within design and engineering has been made easier with the arrival of a smart tool that automates laborious calculations and supports interactive 3D modeling. This allows designers to focus more on the design, work 3-5 times faster, and makes urban planning and design process a lot more flexible and transparent.

Developed by AgiliCity, powered by Techstars x Arcadis, Modelur is an easy-to-use and powerful parametric urban design software tool that embeds planning regulations in the design process. Embedded regulations alleviate the design process from constant compliance checks and give more freedom to explore possible solutions. At the same time, its Interactive 3D Zoning™ method adapts buildings automatically, making sure the maximum site potential can easily be achieved. This allows the designers to quickly create and adjust conceptual urban massing by calculating key urban parameters on-the-fly, offering the fastest path to the design of a high-quality built environment that is in line with both, developer's requirements and the vision of spatial development of the city. Due to the ease of use, one can quickly create and iterate multiple design options to support comparison and decision-making processes among different stakeholders. By incorporating computational parametric design technologies, the program from AgiliCity augments and transforms the design process by increasing efficiency and allowing designers to pursue their development goals without being caught up with computations related to each iteration. The imagination process is freed up from considerations towards constraints and quantitative measures, allowing the designers to quickly create concepts that meet the aesthetics criteria, developer requirements, and regulations compliance at the same time.

MOTION

Many cities across the world are struggling with growing congestion, accidents, overcrowded transportation, and roadside pollution. To solve these issues, vehicles in the future are expected to become ACES: Autonomous, Connected, Electrified, and Shared. AI plays a vital role in all four elements, thanks to its processing, control, and optimization capabilities, and will have huge impacts on safety, reliability, efficiency, and sustainability.

The safety of people while moving will be greatly improved thanks to the ability of AI to predict future flows of people and peaks and to learn how to drive. This capability is especially important in the aftermath of the COVID-19 Pandemic, which led society to add a new facet to mobility safety: social distancing. The need for people to keep distance has certainly created challenges for public transit operators, but AI can support the management process by predicting in real-time the occupancy levels of arriving busses and trains to passengers waiting on the platform, in order to guide them to less crowded sections. AI can also predict travel demand and inform the transit system in order to optimize resource allocation. Similar principles can be found in predictive traffic flow to advise policies against congestions or in designs of infrastructures to maximize mobility flow.

Natalie Sauber
London, UK

Leading Market Intelligence and Future Mobility across Arcadis for over 8 years. Natalie is responsible for tracking the latest trends, technologies and solutions impacting the Built Asset sector with a strong passion in all things mobility (EV, CAV, MaaS). Experienced management consultant with a background in the automotive sector focusing on strategy development, thought leadership and competitive intelligence.

Yuan Shi
New York, USA

Yuan Shi is the Global Solution Leader for New Mobility at Arcadis. She has a background of urban data science and has been applying her technical skills and knowledge to improve mobility systems and other smart city domains for the last 4 years.

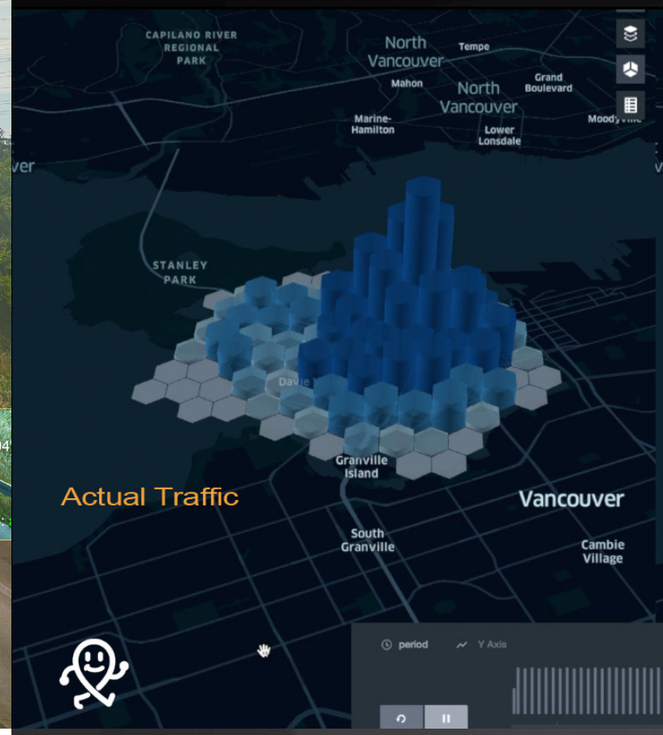
Moreover, as mentioned, the development and future adoption of self-driving cars will be able to reduce traffic accidents by as much as 90%, hence avoiding the death of approximately 1.35 million people each year. On a commercial level, self-driving technology has already taken the trucking industry by storm. Mercedes-Benz, Volvo, Uber, Google, and Tesla are just a few of the many companies competing to make the best self-driving trucks. Considering the high risk of the profession due to fatigue (truck driving is the eighth most dangerous occupation in the US), autonomous trucks are safer, more fuel-efficient, and contribute to congestion reduction, the impact of which is quickly realizable in our industry where shipping and logistics play an integral role. Further adoption of this technology, however, is dependent on additional tests and regulations in terms of safety and cybersecurity for both personal driverless vehicles and trucks. AI will also be able to improve safety while driving by enabling vehicles to communicate with the environment around them. The service, called Vehicle-To-Everything (V2X), is a technology that enables cars to communicate with one another (Vehicle-To-Vehicle) and with external systems such as streetlights, buildings, or even individuals, using sensors. This capability dramatically improves drivers' safety as well as the one of pedestrians and cyclists. It also implies the integration of smart technology is not only limited to the vehicles itself, but smarter infrastructures, urban planning, and construction can greatly advance autonomous mobility.

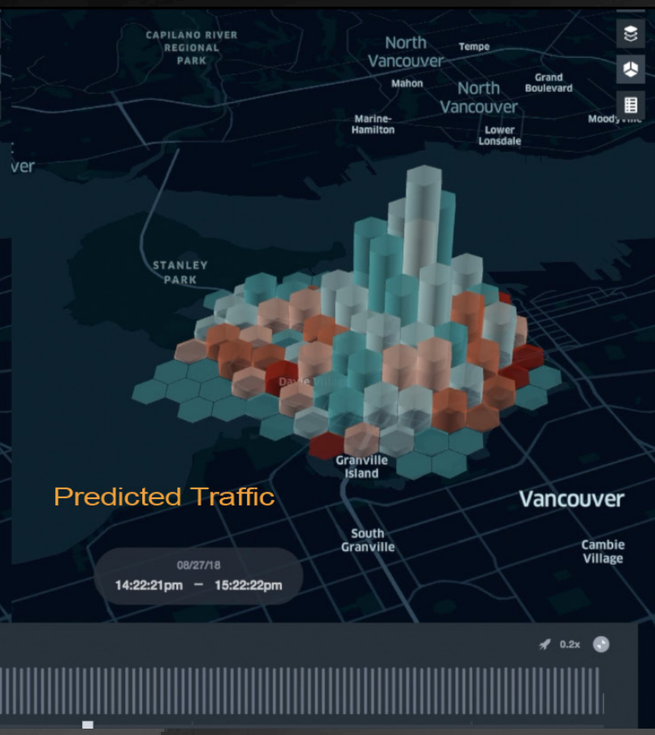
Additionally, the use of AI in mobility will allow to significantly improve efficiency as well as to influence the behavior of drivers. It is estimated that traffic congestion costs more than 1% of the global GDP, and one way of easing the problem is via sophisticated traffic-management systems such as dynamic tolling. Dynamic pricing balances supply and demand, whereas traditional pricing sets prices according to long-term supply and demand. AI can support the dynamic approach by offering short-term predictions to inform dynamic pricing and to help adapt to spontaneous changes in the marketplace. Mobility-as-a-Service (MaaS) also offers alternative methods to influence the behavior of people. MaaS is the integration of a variety of different transport modes in a single accessible on-demand platform with navigation and payment system. AI's prediction capabilities allow mobility operators to balance supply with demand. In the future, all transport modes could follow a dynamic pricing structure in conjunction with MaaS, leader to fewer cars on the roads.

The capability of predicting supply and demand is one of the core assets of ride-sharing companies and could lead to great advantages for the implementation of autonomous vehicles: the fleet operation could be further optimized without considering drivers' preferences. Therefore, all ride-sharing companies are exploring the potential of AI and driverless cars. At the forefront of the innovation, we can find Uber and Lyft in the US, Gett and Bolt across Europe, Daimler's MyTaxi and Hailo in the UK, and Didi Chuxing in China. The future introduction of these cars will challenge how the current vehicles and services are designed. For instance, ride-sharing companies will need to consider whether individuals would want to share a small vehicle with another stranger, or if they will prefer a shuttle space with more people per ride.

The use of AI in mobility can also significantly improve business operations. For mobility service users and operators, the efficiency gains translate to economic benefits by reducing for example operational costs. For asset managers, AI can also help to forecast maintenance for infrastructure and fleets, thus resulting in increased efficiencies across your asset portfolio. In addition, aerial drones and image recognition provides new means to collect data and to inform management, maintenance, and inspections of bridges, tunnels, and construction sites. Taking it one step further, AI can greatly improve the development of mobile robotics for construction sites. While robotics has allowed for significant leaps in efficiency in manufacturing and shipping by performing repetitive tasks, robotics in construction and engineering settings must address the challenges of more unpredictable landscapes and other factors involved with being in an uncontrolled environment. As AI technologies advance towards better recognition of surroundings and decision-making with regards to more complex environments, robotics can support with more tasks surrounding a project. Applications can greatly increase efficacy, accuracy, and even workplace safety by outsourcing more laborious and dangerous on-site tasks to machines. In recent years, exciting pilots have emerged thanks to advancements in AI including autonomous load carriers, demolition robots, autonomous concrete floor robots, and brick-laying robots. As AI gain further tractions, robotics is expected to gain more attention and widespread applications within the industry.

Finally, AI can significantly improve the mobility sector by making it more sustainable. Currently, the transportation sector is one of the largest contributors to greenhouse gas emissions. Driverless vehicles may offer a promising sustainable alternative, as these machines will be more efficient at driving than humans, and the connection with AI-enabled traffic lights would allow to adjust them to the flow of traffic to minimize driving time and contribute to reducing air pollution. Additionally, AI will also make renewable energy technology like solar panels and wind turbines more efficient and cost-effective. Smart grids, a technology enabled by AI will change the way electricity is produced and distributed to homes and to charge points for electric vehicles, by being able to make real-time adjustments for efficiency. Ultimately, AI will profoundly shape all areas of mobility, many of which are relevant to our industry, and more and more applications will be developed in the next years.





CASE STUDY

Downtown.AI

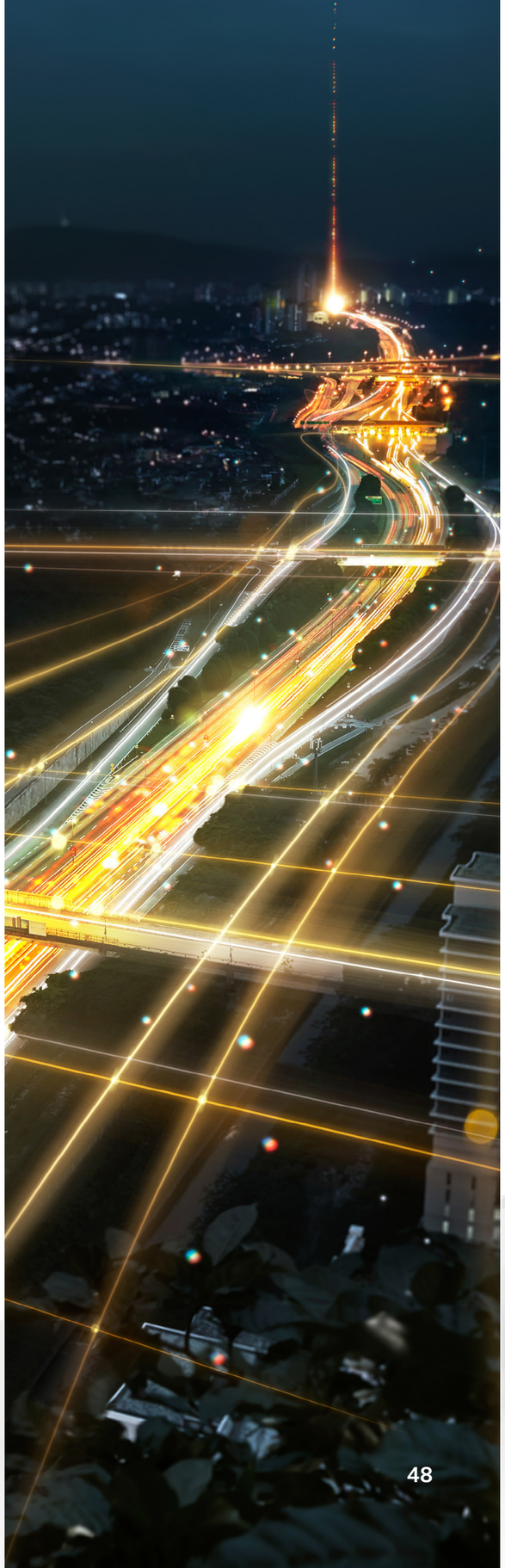
Being able to predict human mobility in urban centers is crucial to adjust urban planning accordingly but also for enabling future developments in autonomous mobility. However, recent changes in consumer behavior and modes of transportations have made the current predictive models outdated. Indeed, people are increasingly choosing public transportations and alternative means of transportation to move within urban areas. The trend is supported by new legislation and increased attention to public transportation routes from the administration. Moreover, the current measurement approach – constituting of hardware sensors, manual counting, and surveys – is not only costly and laborious but also extremely slow, hindering the adaptation of the existing models. Downtown.AI leverages proprietary machine learning algorithms and accurate mobile location datasets to improve the prediction process of human mobility. The platform integrates historical data (often up to 4 years old) on traffic and human movements - gathered from mobile devices - with census data and information on cultural events and transportation systems. Ultimately, they are able to generate insights and predict current and future traffic volume, direction, and speed in a given geography. The results can be then analyzed in real-time through an interactive visualization able to map and predict the movement of the city population including different modes of transportation or by specifying demographic segments or commute behavior.

Downtown.AI's platform has a rate of success for an hour-by-hour human movement prediction of 80-90%. The high accuracy can be leveraged for many urban mobility projects. For instance, the platform enables Smart Mobility Services, such as carsharing, ride-sharing, and micro-mobility, to accurately forecast customer demand and pick the best cities to expand to and to optimize placement of vehicles and assets. Furthermore, the service can be used by public transportation authorities to improve the planning of new infrastructures such as stations and intersections and to optimize the scheduling of public transportation to avoid congestion. Finally, the platform can also support the planning process of infrastructures such as airports and malls.

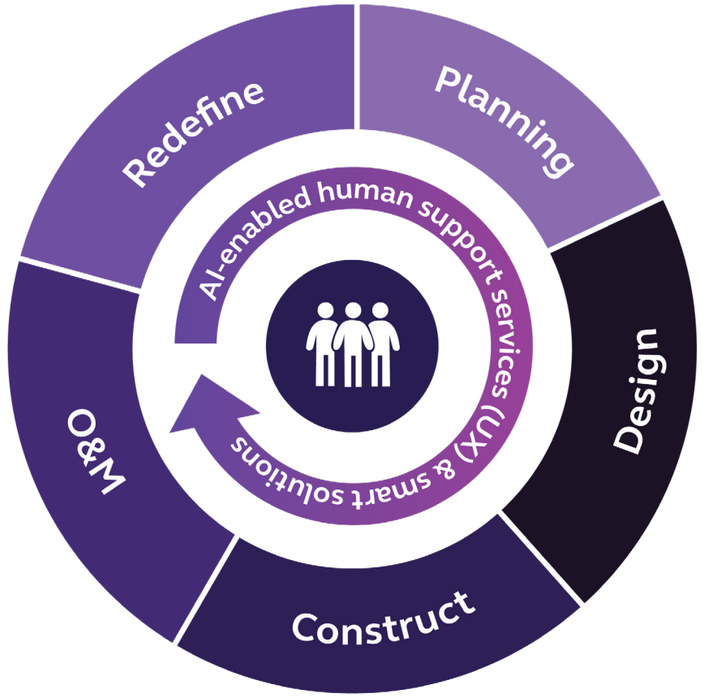
AI Applications in different areas of the AEC Industry

With the rapid development of AI technology allowing for increasing accurate simulation of human intelligence across a larger range of tasks, adoption and integration of these technologies can be seen across different areas of the AEC industry to better achieve their goals.

Activities within the AEC industry span across the stages of assets' lifecycle, with the main goals being maximizing the assets' social, environmental, and economic value throughout their entire lifecycle. Exerting technical, management and consultancy skills, or different combinations of the three, companies within the AEC industry provide value for clients in form of planning, designing, constructing, operating, maintaining, and redefining assets.



Digital Asset Lifecycle



In order to create value throughout the asset lifecycle, operators within the AEC industry provide a variety of services and activities surrounding the assets. These activities can be assigned to six main areas:

Cost and Commercial Management
Operations and Management
Business Advisory
Program Management
Design and Engineering
Environmental Restoration

The application of AI takes shape in different manners across different stages of an asset lifecycle but in their broadest forms, they augment the human support services or enable the creation of smart solutions to the process. Adopting these technologies that increase the effectivity and efficiency of tackling challenges found in each stage of the lifecycle, sharpens the focus on the central mission of improving the quality of life in communities.

The section below shows deep dives into each of these major areas of the AEC industry, and how AI technologies are currently being applied to help achieve their respective goals.

Andrew Beard

London, UK

Professionally qualified quantity surveyor with over 15 years of experience is now Global Head of Cost and Commercial Management for Arcadis. He is accountable for creating sources of competitive advantage for the business and its clients, innovation, and new products, delivering sustainable growth as well as maintaining our leading position globally and across prioritised regions and sectors.

Stephen Peters

Sydney, Australia

Stephen is an energetic detail-focused quantity surveyor/cost manager who is zealous about incorporating technology into work practice and driving the profession and industry forward. Stephen has been involved with digital quantification and estimating on some of Australia's largest infrastructure projects, such as: Sydney Metro, Melbourne Metro and West Connex.

Matthew Mackey

Brisbane, Australia

Matthew is a professionally qualified quantity surveyor working across both the property and infrastructure sectors for over 21 years, with a large portfolio of experience spanning the UK, Europe and Australia. Currently, he is the Product Owner for Cost Clarity, which is an online application designed to improve and maximize client experience.

COST & COMMERCIAL MANAGEMENT

The future of the Quantity Surveyor (QS)/Cost Manager, and of our Cost & Commercial Management business, is rapidly changing – and the rate of change, and the frequency of adaptation required, is becoming quicker.
Artificial intelligence is defined as machine learning to mimic human intelligence. The computer learns how to respond to certain actions, so it uses algorithms and historical data to create something called a propensity model. Propensity models will then start making predictions based on previous actions to carry out tasks with extreme accuracy. There is almost no doubt that this next wave of technology will grace the QS world at some stage soon, with undoubtably more doomsday predictions about the end of the humble cost manager - as was purportedly the case with 5DBIM.

However, optimists with an eye out for the future believe that the adoption and artificial intelligence and machine learning can greatly enhance and augment our current service offering. We have provided below a snapshot of the steps that companies within the industry are taking to both embrace and take an active role in leading these advances in technology.

Artificial Intelligence and Cost Planning

Construction cost estimating and cost planning is a vital component of any project as it has a significant effect on related activities such as:

>> Planning and design
>> Tender
>> Cost
>> Construction Management

Ultimately, cost estimating, and cost planning are cost control measures adopted by the cost manager in the absence of complete information during the pre-tender stage. We are reliant on a combination of historic cost data and previous experience. However, this reliance has its limits particularly due to the large number of variables that are inter-related with one another. Therefore, to address this challenge and to improve the accuracy of construction cost estimating and cost planning, the adoption of computerised algorithms is inevitable.

Artificial Intelligence and machine learning potentially hold the key to improving the accuracy of our estimates and cost plans. This can have a significant impact on client decision-making in several areas, including the approval / rejection of alternative design solutions and the selection of the materials. We can also utilise machine learning to better predict the likely impact of certain scenarios on project budgets and cost estimates – particularly when this is combined with our vast database of cost benchmarking, trend data and project knowledge. This partnership of machine learning and real data will drive our predictive analytics and enable us to advise on the impact of multiple scenarios, such as:

>> The potential cost / trend impact of using a particular procurement methodology or contract.

>> Understanding the level of design completeness and how this may impact future contract variations and the anticipated final cost.

>> More accurately predicting market changes and the potential impact on construction pricing inflation.

>> Early identification of common risks associated with a procurement approach / contract / asset type.

The benefits of this approach are just as powerful for the cost manager as they are to our clients. Our role will shift and transition from quantification to one of articulating value. Rather than spending a disproportionate amount of time preparing quantities, we will be able to spend more time extracting value out of a project during the planning phase, as this requires a lot of communication, engagement, and coordination – something that a computer simply will be unable to undertake.

With digital transformations taking place across the industry, digital cost reporting platforms represent a quantum shift in the delivery of cost management services in providing clarity and with client experience built into its core. Digital cost reporting platforms can and will provide clients with instantaneous access to their project cost data. It will challenge and improve project performance by automating the generation of advanced analytics, automated dashboarding and visualization to provide near real-time insights. The digitalization of the process and increasing incorporation of intelligent analytics will provide our clients with an elevated understanding of the cost impact of their decisions, allowing them to make data-informed choices.

Machine learning is also doing more for us than headline quantification and predictive analytics. It also serves to remove manual and mundane tasks – giving the cost manager more time to focus on the parts of our service that provide relevance and value to our clients.

Within CCM, Robotic Process Automation (RPA) have been used to replace the manual tasks which cost managers would have delivered as part of their scope of services. The use cases have included application for payments, cost reporting and cost verification / control.

RPA has also been used in conjunction with Computer Vision for initial use cases including automating the review of design drawings and outputs. Specifically, the review and recording of design documents and the updating of drawing lists to ensure the most up to date information is being used and referenced correctly in our cost management outputs.

Furthermore, the advancements of design packages allowing multiple options and solutions to be produced has been significant over recent years. We have been working with designers to identify and draft the constraints and code upon which improved options can be developed based on value for money and cost considerations. This allows not only design solutions which best meet a technical brief to be identified quickly and efficiently but also design options which optimise the relationship between cost and value or take more advanced considerations of efficiency benchmarks and financial constraints and budgets – often linked to the value drivers of the project.

Finally, AI is the solution to achieving 5DBIM. Without BIM (Building Information Modelling), quantity automation, machine learning and artificial intelligence becomes impossible. Through working on several projects that have used BIM, it has become extremely evident that there is no 'one-size-fits-all' approach to the creation of 3D models and that there is little standardisation between design consultants.

Therefore, extracting quantities and associated information from a model requires a considerable amount of analysis and manual coding for each element and component to minimise inaccuracies and inconsistencies in both quantities and the project scope. This negates any of the time saving benefits that the 5DBIM process should be realising. This has resulted in a significant 'roadblock' in the application of 5DBIM across the industry as the models that are being created are unreliable and inconsistent – rendering it almost impossible to fully automate the quantification process.

Whilst there have been a lot of drive and commitment, from within the quantity surveying profession and the industry as whole, to adopt and progress 5DBIM, we believe that it is an impossible task with the integration of machine learning and artificial intelligence. It is to this end that we all need to be investing heavily in our digital capabilities.

Whilst we have the capability to manipulate BIM models to extract and price quantities, we do not believe that this fully enables 5DBIM to realise its full potential. There is still a static and manual update that is required to pricing in cognisance of changing design elements and dimensions or to reflect the addition or omission of elements.

Artificial intelligence and machine learning can provide the answer – it will intuitively recognise a change in element or dimension and, consequently, understand the potential cost impact of that change. This will allow the cost manager to spend less time quantifying and measuring and more time focusing on pricing, benchmarking, trend analysis, and value realisation.

CASE STUDY

Cost reporting using robotic process automation

In late 2014, Arcadis was awarded the cost consultancy services for The Royal Atlantis Resort & Residences, which is a 360,000^{m2} luxury development located in the prestigious Palm Jumeirah in Dubai. Due to the size and complexity of the project and the breadth of supply chain involved in its delivery, the amount of cost information to be managed meant that carrying out routine reporting processes were a significant undertaking. In addition to the reports being very detailed and technical, they also needed to be integrated with the client's cost management software, the variation workflow process and the contractor's own cost reports.

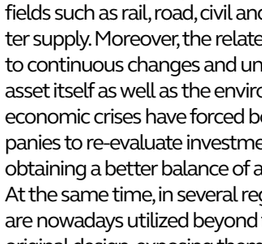
We identified that a significant amount of time was being spent on manual and repetitive reporting tasks and aligning with the client's costing structure requirements, especially if we were to employ traditional, manual methods. As a solution, and in collaboration with one of our new eco-system partners, First Consulting, we utilized Robotic Process Automation (RPA) to minimize the time spent on reporting and allow senior cost consultants to focus on other important deliverables. RPA was programmed to complete three detailed processes including collecting data from serval locations; checking, reorganizing, and collating the data into a final summary; and placing the final produced tables in a Microsoft Word-based report. Through RPA, 80% of the manual work can now be completed by the robot. This process, which used take a senior consultant up to seven working days to finish, is now delivered within two hours through the adoption of new robotic methods. Through using RPA, we were able to redeploy the time saved to agree variations as desired by the client and add further value to the project. As the project becomes more complex, the administrative aspect of producing cost reports has been made more efficient by the implementation of RPA. However, we have only scratched the surface of this new digital delivery tool, which when further scaled, could help efficiently deliver major projects and programs in the future.

As a business and in line with our digital transformation strategy, RPA is becoming increasingly important for us as it eliminates manual, repetitive tasks, and subsequently enables us to drive greater efficiency in the delivery our services. In the initial phase of RPA deployment, its utilization has been particularly scalable in elements of our service delivery that require the gathering of data from multiple sources to support the reporting process. RPA will further act as an enabler of more advanced analytics, which will subsequently support the differentiation of our services.

OPERATE & MAINTAIN

Spanning across all the different phases of the lifecycle of an asset, operation and maintenance responsibilities play a critical role. Due to this constant need for Operate and Maintain (O&M) throughout an asset lifecycle, this area is the costliest and also the longest process in ongoing duration, especially in fields such as rail, road, civil and hydraulic structures, and water supply. Moreover, the related processes are highly prone to continuous changes and uncertainty with regards to the asset itself as well as the environment it is situated. Recent economic crises have forced both governments and companies to re-evaluate investments in assets and to focus on obtaining a better balance of asset costs and performance. At the same time, in several regions of the world, many assets are nowadays utilized beyond the designated lifetime of their original design, exposing themselves to considerable risks, worsened by recent environmental shifts.

With the increased amount and intensity of data collection from recent waves in digitization of assets, AI integration into the O&M process is needed in order to properly manage this stream of information and automate related processes. Furthermore, society's increased level of interconnection results in a larger amount of information shared amongst all stakeholders and, in turn, in increased demand for more transparent and more sustainable solutions. This trend is also supported by the higher number of laws and regulations for more financial and operational transparency. These challenges contribute to the increased complexity of the ongoing asset management process. Facing this, organizations need to leverage their expertise to improve the current management process given the constraints and learn how to better implement innovations within the business to gain competitive advantage.



Don Hardy

Amersfoort, Netherlands

Don is the strategic advisory in digitization and transformation of asset management services, including related innovation, business development and commercial propositions.
He has been the Arcadis global lead for asset management over the past four years. Before being part-time with AM/FM services, he was more focused on the real estate.

Similar to other phases of the lifecycle of an asset, O&M has also been an area significantly disrupted by the ongoing digital transformation within the AEC industry and by the introduction of AI-based technology. Being able to leverage the potential of this new technology and integrate it within all processes is crucial for the success of the organization. AI capability could especially support a crucial but sub-performing area of asset management: asset maintenance. In a 2020 report from Arcadis in collaboration with Bluefield Research about future proofing assets , maintenance has been slowly shifting towards a reactive approach, mostly due to underinvestment from the part of asset owners and companies, which leads to 25-30% of the assets operating beyond their designated life.

Furthermore, amidst the COVID-19 pandemic, it is already clear that the 'new normal' includes a significant acceleration of using digital tools and digital asset management. The application of artificial Intelligence could greatly improve the maintenance phase of assets through different AI-based tools, such as computer vision and IoT. Computer vision is an AI technology capable of automating the process of asset inspection which includes object detection and identification, as well as higher level information procurement, from images, enabling for inspection activities to be greatly automated and the asset conditions continuously and digitally tracked over time. The process involves teaching machine learning algorithms to recognize specific target objects within picture frames based on previous human classifications and also from own operations, determining with an accuracy metric of 95% on average if there is maintenance needed. Alongside to automated inspection using computer vision, the application of IoT technologies is increasingly popular in engineering and construction projects whereby sensors can provide live reporting of asset conditions via the development of Digital Twins without the need for on-site inspections. The separate or combined usage of technologies such as IoT and computer vision to the O&M phase thus greatly reduce costs of asset maintenance by capturing information at a faster pace and with more effectiveness, allowing for asset managers to be continuously updated about the state of their assets in order to react accordingly in time if not in advance.

However, digital asset management still has several barriers to overcome – perceptions of cost, the challenge of change-management and cultural issues, and finding the right advisory and delivery organizations to help – but it's clear that the coming months and years will be unprecedented in the changes that they will bring.

With the shift towards digitized data collection, large leaps within analytics and data processing technology must be adopted within O&M to properly handle and extract values from the stream of information that technologies such as computer vision and IoT bring in. Firstly, a data management strategy is needed as well as advanced analytics applied in the process searching and generation of knowledge. Common data environments – available anywhere at any time – provide a single source of 'truth' which can greatly improve optimization and decision-making. Digital tools also help drive standardization, automation and productization.

Similar to other phases of the lifecycle of an asset, O&M has also been an area significantly disrupted by the ongoing digital transformation within the AEC industry and by the introduction of AI-based technology. Being able to leverage the potential of this new technology and integrate it within all processes is crucial for the success of the organization. AI capability could especially support a crucial but sub-performing area of asset management: asset maintenance. In a 2020 report from Arcadis in collaboration with Bluefield Research about future proofing assets[7], maintenance has been slowly shifting towards a reactive approach, mostly due to underinvestment from the part of asset owners and companies, which leads to 25-30% of the assets operating beyond their designated life.

Furthermore, amidst the COVID-19 pandemic, it is already clear that the 'new normal' includes a significant acceleration of using digital tools and digital asset management. The application of artificial Intelligence could greatly improve the maintenance phase of assets through different AI-based tools, such as computer vision and IoT. Computer vision is an AI technology capable of automating the process of asset inspection which includes object detection and identification, as well as higher level information procurement, from images, enabling for inspection activities to be greatly automated and the asset conditions continuously and digitally tracked over time. The process involves teaching machine learning algorithms to recognize specific target objects within picture frames based on previous human classifications and also from own operations, determining with an accuracy metric of 95% on average if there is maintenance needed. Alongside to automated inspection using computer vision, the application of IoT technologies is increasingly popular in engineering and construction projects whereby sensors can provide live reporting of asset conditions via the development of Digital Twins without the need for on-site inspections. The separate or combined usage of technologies such as IoT and computer vision to the O&M phase thus greatly reduce costs of asset maintenance by capturing information at a faster pace and with more effectiveness, allowing for asset managers to be continuously updated about the state of their assets in order to react accordingly in time if not in advance.

Secondly, predictive analytics basing on past data are the essential next step to enable asset managers to predict future failure moments for an asset or a component in order to schedule timely maintenance. The ability to predict failure optimizes the asset maintenance process and avoids interruption to the asset operations. This technology relies on an AI algorithm which can learn how to identify a possible future failure by training on historical data concerning different characteristics of the asset in consideration and therefore can quickly identify anomalies in patterns and flag as potential failure. Moving from a reactive maintenance approach to a predictive one can significantly improve the overall process. The AI technology is, in fact, able to greatly reduce the budget spent on fixing failures, while at the same time maximizing the efficiency of the asset.

Organizations that have embraced a preventative approach to asset maintenance and refurbishment are reporting a reduction in maintenance budget of up to 50% over three years. These organizations are using sensors and advanced data analytics to advanced data collection tools and technology, coupled with sophisticated data analytics to identify assets that need refurbishing before they fail. Post-pandemic, the greater volatility and uncertainty in the marketplace will necessitate earlier engagement with sector- and industry experts within supply chains. It is important for the shift towards AI technologies to try to gain agreement from all key stakeholders about the benefits of a single enterprise-wide digital asset management system. These players need to understand the opportunity cost of replacing legacy systems and inefficient processes, and the longer-term benefits of a true optimized digital asset management approach. It's worth being realistic about own enterprise goals. If the promise of an enterprise-wide, all assets in a single system, single-version-of-the-truth is too much of a stretch, consider Software As a Service models which use industry-specific best-practice templates to allow go-live with a minimum viable product in a short timescale.
Ultimately, being able to fully leverage this opportunity will represent a source of competitive advantage for the company. Indeed, by establishing predictive maintenance processes, it is possible to provide high quality asset management which also enables improved decision making and insights. Overall, the quality of the service and relationship with the client will greatly improve. In general, AI has a large positive impact on O&M by providing benefits not only to the project company but also to the clients by greatly reducing inefficiencies and error, thus making the overall task less time consuming, less risky, les uncertain, and more efficient. These improvements translate into better performing assets and lower costs for the client, thanks to reduced failures and problems.

From the O&M perspectives, organizations who are able to fully integrate this technology into their business processes will thrive. Indeed, amongst the uncertainty and market volatility that will characterize the industry in the future, being able to navigate through the uncertainty and understand the condition of aging assets in order to know how to prioritize their repair will be crucial. As AI technologies rise in prominence for O&M, organizations are facing increased pressure to pick the 'right' digital solutions in an increasingly fragmented and diverse technological landscape. Investments in internet of things (IoT) platforms, supervisory control, and data acquisition (SCADA), operations and enterprise management platforms and digital twins have very different payback periods to more traditional capital investments. Additionally, this new era of market volatility reinforces the urgent need for organizations to prepare for a prolonged period of uncertainty. Unfortunately, doing nothing is not a viable option in the case of O&M, and although the future is difficult to predict and will depend upon the scale and timeliness of government interventions around the world, it's clear that the future will involve trying to manage the increasing complexity that comes with intelligent assets, and embracing digital tools and services for greater optimization. Future proofing also means being better prepared to accommodate changes to the environments and changing demands from stakeholders with regards to sustainability, and AI technologies play an undeniable role in this agility in face of ongoing as well as unexpected challenges.

[7] Arcadis. (2020). *Future-proofing assets amid uncertainty.* Amsterdam. Retrieved from https://www.arcadis.com/media/9/C/1/%7B9C1C4172-04A3-4390-8A95-41533029AA1A%7DArcadis_Future-Proofing_Asset_Brochure.pdf

CASE STUDY

Rail asset detection

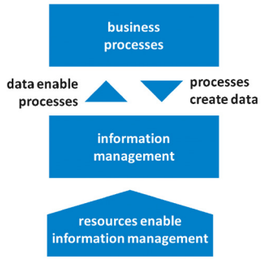
Due to new safety standard by the US government, PTC regulation, the railroads like CSX have to always be in control over their assets. Especially signals are critical in this system as they communicate with the train and can slow them down automatically. Our client, CSX, had various data sources to get insights from, ranging from imagery to point clouds, but due to the size of its tracks a manual analysis proved to be impossible. CSX has over 100.000 assets on more than 20.000 miles of track. The goal was to roll out a tailor made, efficient solution to CSX's network, in which their experts only have to look at any irregularities, either due to changes in asset location or disturbances in data capturing.

In order to achieve this goal first, annotated footages were used from CSX, assets of CSX and their geolocation are labelled along with distance calculations of track width and distances to assets. This is then used by Arcadis to train a Deep Learning model with over 5000 images with all asset classes and their positions. The object detection model automatically classifies all rail assets along the track together with their locations relative to the track through footages from cameras mounted in front of trains. After the identification is finished the identified assets are saved and integrated in ArcGIS (Geographic Information Systems) and available in different formats where the results of the classified assets and their locations are visualized for an up-to-date asset inventory.
At last the model is finetuned based on client input, Arcadis US input and the latest collected data.

The combination of computer vison and point cloud segmentation proofs to be especially strong in the infrastructure domain. The object detection model can classify the objects along the rail track automatically without any human input, with the hit rate on signals of >99% accuracy, at a much faster rate than on-field check or digital inspection. Furthermore, since the model uses Artificial Intelligence, the model will improve with more collected data, thus getting more accurate with every new run. Additionally, the exact location of the camera is stored (GPS) so that the location of assets can be determined in each image, resulting in a single classification per object. Subsequently, the locations of the results are visualized in ArcGIS, allowing for accurate and accessible up-to-date inventory to be reported almost immediately (a diff report). Finally, the model is adjusted for standard cameras like a GoPro, making it easy and cheap to implement, and for advanced and expensive equipment like LiDAR. Even the signals itself or specific details like the lamps are visualized and accurately positioned. The use of image recognition technology enables for further cost reductions as well as increased health and safety from the elimination of the need to physically send teams into the field to collect asset location. The automation of data entry means that the data is highly accurate and real time insights can be obtained with regards to the current status of the vast rail track.

BUSINESS ADVISORY

In the age of data, Business Advisory is an area where domain expertise, consulting skills and digital know-how are brought together to meet the needs of the market and clients to deliver better outcomes, and data and analytics is at the heart of the missions. Specifically, this entails supporting the transformations of business, maximization of built and natural asset bases, and provision of finance and investment solutions.



Within Business Advisory, digital capabilities are underpinned by industry experts with extensive cross-sector knowledge and experience and vice versa. Specifically, strong data management and data architecture is important to provide a foundation for organizations to meet obligations in highly regulated and asset-intensive environments and at the same time meet stakeholders' demands to protect the public and the environment. For complex asset-intensive organizations, Business Advisory plays an essential role in providing technical and strategic guidance on large data management and information architecture programs, the foundation of which can improve the quality of decision-making and customer outcomes.

Sarah Wilkes

Birmingham, United Kingdom

As Global Solution Lead, Sarah is heading the portfolio of Arcadis' offerings. She is leading the strategic focus to ensure our clients' needs are served best. She has a strong background in business advisory and more than twenty years of experience working in the AEC industry.

The main mission is to help clients or related business functions understand how to govern and manage data to deliver superior operational and strategic value, facilitating and driving board-level organizational change. In delivering effective data solutions, the objective is to optimize the value of data and drive operational efficiencies, performance improvements, and regulatory compliance.

With growing data availability rising from commodified AI technologies, advanced data analytics has in recent years gone from a tool of competitive advantage to becoming an integral and expected element of Business Advisory. Through a combination of data management, machine learning (e.g. data mining), and data visualization technologies, advanced data analytics can access relevant information and extract valuable insights with regards to asset conditions and project progress at lower costs automatically and almost immediately. Taking it a step further, advisors can leverage data-informed decisions further with applications of predictive and prescriptive analytics which drives risk management strategies and allow for maximized data-informed decision-making.

Traditionally, Business Advisory business models rely heavily on the labor-intensive task of research, data extraction, analysis, which eventually provide recommendations. With the integration of accessible data analytics into Business Advisory functions, the process is significantly shortened, becomes more cost-effective, and business decisions shift its dependency on managerial intuitions and practice towards being more data-informed. With data mining and big data analytics, the process of analysis can be ongoing and parallel to other research processes and revealing insights that might be missed when traditional methods require predetermined objectives and questions. Thanks to the increased speed and ease of information processing, decisions stemming from insights are also more relevant as effective data management enables for real-time availability of information through automated analytics, as well as modeling future impacts basing on different decision alternatives.

Not only does AI transformations impact the performance of Business Advisory, it also demands new services. As one of the last industries to digitize, the current focus within the Business Advisory area within the AEC industry is related to providing support for robust data management strategy to align the project or organization's strategic objectives with operational imperatives through enterprise and data architecture services. For instance, this can take the forms of the implementation of Master Data Management processes and strategies, reference data warehouses and their interfacing to feeder systems, particularly in the business information, reporting, engineering and asset knowledge domains.

The delivery of data management and architecture services can use the following business-led and versatile approach that utilizes agile, scalable, and innovative methods. The approach has the following five phases:

1. Governance by Design: Data is a valuable resource which needs to be structured and controlled in the right context to enable the business to be able to harness its benefits. By building data governance into the DNA of the enterprise, an organization is able to harness the power of their data from the start, and enabling the business to realize unique insight in the future and value from its data architecture to enable cost efficiencies, and improved outcomes.

2. Enhanced Decision Support: Application of data engineering principles allows for the combination of critical operational and project data to create a single source of the truth and a clear understanding of operational status that drives superior insight and decision-making. This enables enhanced decision making from concept and business case to operational effectiveness and continuous improvement.

3. Digital Leadership: The ideal data architecture approach utilizes a multi-discipline team of highly trained experts from data scientists, domain experts, enterprise architects, and digital change leaders to enable concurrent solution and architecture development that eventually can be accessible to all relevant stakeholders. This ensure the positive changes are made from the mobilization of the project with longer lasting knowledge being sustained into the business.

4. Architecting Data Performance: Data links and interconnects the people within an organization, their suppliers, their clients and drives their performance. Using enterprise architecture techniques to visualize and model the data entities, clusters and their importance to the end-to-end business value chain. Strong engagement with the users and stakeholders to define conceptual models to quickly identify the value and importance of an organization's data enterprise on operations and overall business performance.

5. Enterprise Data Agility: For data architecture to deliver its full potential, there needs to be a comprehensive and complementary enterprise architecture. An integrated enterprise architecture and data architecture result from the capability of multi-disciplined and highly experienced teams of data, project, IT and domain experts who enables agility in building the data architecture and solutions, capturing the knowledge to project and domain needs. It provides an approach which is continually adapting to change as the teams progress throughout the process. This sets the foundations for governance with a quality and secure by design approach, enabling real domain insights and useful knowledge to be captured from the start.

Looking forward, as the market matures and adopted AI to optimize their environments, the aim is to have embed data, analytics and AI into all services provided by adding AI as a key pillar to Business Advisory services to deliver even better outcomes for clients.

Firstly, with a robust data management strategy in place enabling for automated analytics and data collection, it is expected insights to be available at real-time and reporting to be instantaneous and as per request to the advisory service providers as well as to clients directly. Within the financial industry, this capability is already being tested with the pilot program between UBS Wealth Management and Amazon's Alexa. With access to data from UBS, wealth-management clients are able to ask Alexa to provide financial and economic indicators and summaries, and it is expected that her analytics function will be further integrated.

As the industry quickly digitize, the need for Big Data analytics with AI and machine learning applications become more imperative for Business Advisory to extract knowledge from unstructured and structured data in order to access the insights needed in order to proceed to recommendations. The focus will increasingly fall on the use of data mining in searching for patterns in this constant stream of incoming information, predictive and prescriptive analytics in guiding unbiased decisions, and data visualization to effectively communicate these findings in comprehensive and accessible manners. This also allows for information to be extracted in the most unbiased manner in which researchers do not interfere with their research agenda and presumed findings.

In the near future, Business Advisory functions will see the need for stronger integration of Data Scientists in all projects, and data literacy among consultant's shift from being a nice-to-have to must-have. Furthermore, it is expected for successful Business Advisory functions across the industry to be the ones who can shift towards a strong digital culture, and those who can establish an ecosystem with the right tech providers to leverage both domain knowledge and technical knowledge. This is imperative to directly compete with the increased number of AI tech providers resulting from the democratization of AI technologies and commodification of data that effectively lowered the barrier to digital consulting. However, unlike tech providers, Business Advisory services with a firm footing in AI technologies as well as management consultancy can continue to add value by providing a holistic understanding, domain expertise, and previous experiences that are complementary to the technologies. In this manner, leveraging both human intelligence and artificial intelligence, Business Advisory holds the promise of delivering values to clients through increasingly effective, timely, and reliable processing of information with higher objectivity. However Business Advisory must hold its strong commitment to AI and analytics technology or stand to be uprooted by big and small competitors alike who can effectively position themselves in the new age of data.

CASE STUDY

Assurance integrator process

This case study is an amalgamation of several assurance integrator implementations, presenting the importance of proper data management in leading up to applying more advanced analytics and artificial intelligence in Business Advisory.

The goals of assurance integration are to produce reliable, verifiable, and timely information that offers better insights about controls, predicts asset integrity failures and defects, and provides leading indicators of incidents that may have health and safety consequences.
Assurance integration originates from a recognition that the current siloed approach leaves unrealized value on the table. Companies are collecting more risk data (operational, production, EHS, HR, asset health, facility and security) than ever, yet management is reporting the lowest level of preparedness in 12 years. Insights that could reduce corporate risk profiles, lower costs and strengthen resilience are going undiscovered. Recognizing data and digital systems as underutilized assets raises the need to consolidate assurance-providing resources, standardize assurance processes and reduce the number of management information systems that have proliferated over the last decade.

The specific challenges the siloed approach includes first and foremost inconsistent assurance processes and with it comes increased operational disruptions by multiple assurance providers. The lack of communication also means that assurance functions are unable to leverage each other's work to help identify priorities. Finally, the proliferation of systems and tools result in many duplications, reports, but fewer insights.

Approaching these challenges, Arcadis used the Assurance Integrator process, which has standardized processes, eliminated redundancies, and harmonized data to streamline the audit process for multiple business functions (e.g., EHS, security and sustainability), minimize facility disruptions, reduce costs and improve the processes that manage risk, with emphasis on continual improvement, compliance, resilience and sustainability. As a direct result, assurance that operational risk is being effectively managed with a reduction in audit time of 40%. This lowered support function costs and, by minimizing operational interruptions, increased manufacturing production. The reduction in compliance costs was approximately 25% (approximately $300,000/year) with 40% reduction in audit time.

PROGRAM MANAGEMENT

Artificial Intelligence can be defined as a collection of different technologies working together to enable machines to sense, comprehend, act, and learn with human-like levels of intelligence. AI relies on large volumes of data and applies algorithms to assist with the compilation and analysis to create predictive trends. As the AEC industry shifts from a design led 3D-Model centric process to a data-centric process, the volume of data created within a project becomes significant. Due to the nature and massive amounts of data to be managed in AEC projects, programs and portfolios, AI is ideally suited to assisting the delivery of Project Management services, augmenting and perhaps over time replacing some of the techniques that are currently used.

Whilst some aspects of AI are still in their infancy there are other areas where their development is more advanced - machine learning, computer vision, smart robotics, autonomous vehicles, natural language processing, and virtual agents. The requirements of Project Management best align with the adoption of machine learning, natural language processing and virtual agent capabilities. In the application of Project Management, the two goals of AI are to improve the overall project success rates and improve the efficiency in delivery.

Paul Madison
Dubai, Middle East

Paul has specialized in the last 30 years in project and program management of properties and buildings. He has experience in delivering large scale project and programs across sectors including healthcare, hospitality, education, retail, residential and commercial developments. Paul strives for creating better value for our clients by better leveraging the value of data analytics.

Liwei Pi
Munich, Germany

Piwei is an experienced project management professional in the real estate consulting with education in computer science and an MBA. She is an enthusiast of AI in Project Management.

Planning and project controls are areas of Project Management where AI can be applied in various ways. Project planning/schedules are effectively large databases consisting of activities, work breakdown structures, resources, budgets, and project constraints. AI will be able to learn from the lifecycle events of other projects, and through data and trend analysis, will allow for intelligent management assistance. By properly dealing with the historical and real-time project data with regards to performance metrics, AI can examine common behaviors within the projects and overall trends through machine learning and data analytics and highlight aspects that might potentially be overlooked (e.g. exceeding costs) or produce predictive analytics to help forecasting budgets and timelines in more accurate manners. It is anticipated that planning projects using AI will reduce risk and improve the predictability of future projects.

Organizations who implement AI in Project Management and deliver a clear value proposition will benefit in many ways. Besides the financial return, there are benefits to employees who are more inclined to stay with innovative organizations and talent can be attracted by high AI maturity in the organization. Furthermore, with AI-enabled project management, many redundant and routinized task processes can be free of human involvement (e.g scheduling), and workers can focus on more rewarding tasks with higher value added. Employees are able to move beyond mindless processes, and projects are delivered at more efficient manners. Ultimately, early adopters will thrive, whereas those who are slow to adopt run the risk of being left behind.
Clients benefit from AI in Project Management too: by selecting to work with a partner equipped with AI-enabled Project Management tools, they can leverage the enterprise knowledge and lessons learned by feeding into the database and analysis for their project(s) with the goal of improving the quality of decision making and the predictability of outcomes.

Project management can greatly benefit from AI-enabled optimization in greatly transforming the processes of decision-making. While the aforementioned applications of AI bring forward insights that would otherwise be missed or helps reduce uncertainty by providing more accurate forecasting, AI can also support in bringing in all available information and prescribe actions. AI technologies are ideal for handling complex analytics, and thus ideal for Project Management where a holistic overview must be realized basing on multiple sources of information and multiple workstreams. Optimization technology has increasingly been applied more diversely within organizations to optimize tactical decisions (which assets should I maintain this month?), near real-time decisions (how should I respond to the current asset condition and the predicted change in demand over the next few hours?) and operational decisions (how should I deploy my workforce to best respond to events over the coming weeks/months?).

More widespread application of comprehensive decision analytics programs can be highly advantageous for the multitude of decisions that are involved in project management. It is expected that Project Managements are shifting away from manager intuition and towards a more data-informed future where AI is woven in throughout monitoring, planning, and deciding within a project. Project Managers must deepen their knowledge of these capabilities to leverage the tools and techniques available from these AI technologies that are here to stay.

CASE STUDY

Global program management using predictive analysis

Under a five-year contract, Arcadis applies advanced analytics knowledge to provide global Program Management Services to an international client from the financial sector together with regional delivery of the client's global capital expenditure program. This is part of a growing trend for corporates to adopt a program management approach to capital expenditure delivery, seeking the additional efficiency and effectiveness benefits this brings. In this particular case, predictive analytics and machine learning are used to enhance less complex decision-making by observing possible performance markers for future projects basing on past indicators.

Using machine learning and historical data, Arcadis applies statistical modelling and simulations in order to be able to predict future variables and values, moreover, principle component analysis is also used to gain insights, and enhance evidence-based decision-making for low complexity decisions related to capital investment planning on account level. Analytics are being run on 1000 projects, project data, regarding country, types, categories, value and dates are being analyzed. The predicted models are able to indicate possible variables and future projects that could be subjected to over-or underspending with higher certainty, allowing for decisions to be made on a more informed basis. Arcadis pushes forward using smart Excel sheets and Power Apps.
With this AI-enabled predictive ability, as global program manager, Arcadis offers the identification of oversights, and provides assurance, planning and control of capital projects, with the aim of improving performance, reducing cost, controlling risk and reducing the client's environmental impact, in a sustainable manner. The process of extracting, tracking, measuring and finally changing behavior is key. Arcadis will also be the primary service provider for project management, cost management, health & safety, sustainability, and risk management for capital projects in the Europe, Middle East and Asia Pacific regions. Advances of the data sets incorporate contract advances, historic cost performance, risk and out of scope benefits.

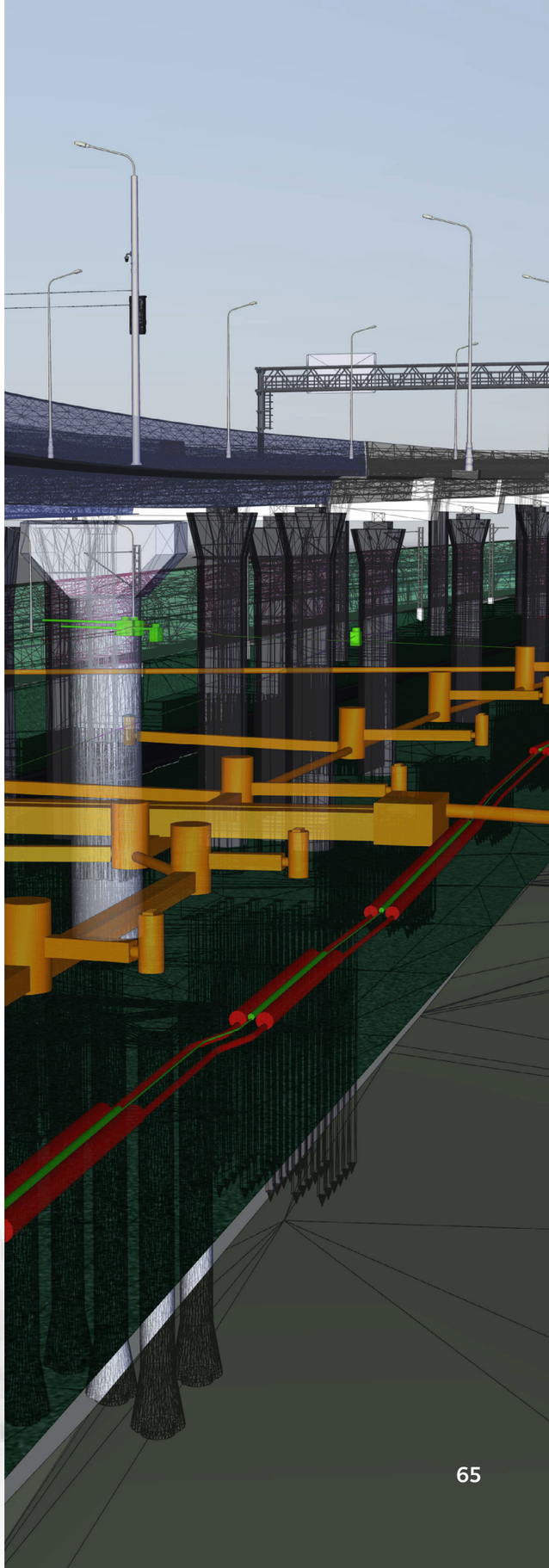
DESIGN AND ENGINEERING

The Architecture, Engineering, and Construction industry has experienced profound changes in the last few years. A digital transformation has become imperative for every player in the industry, and with it innovating the core process of Design & Engineering (D&E) is essential to secure a leadership position in the market. Indeed, D&E is a crucial part of the entire asset lifecycle, and the choices taken during the design phase have a great impact on the Operate & Maintain and Redefining moments as well. Therefore, it is essential to focus on the Design & Engineering process in order to improve the client experience and provide innovative solutions that focus on clients' demands and experiences.

The digital transformation of the D&E phase follows two main priorities. The first focuses on the digitization of the design delivery process, which is shifting towards the adoption of a Level 2 of BIM maturity. According to it, the design is developed in a 3D object-oriented model and in a common project data environment such that it is possible to enable collaboration across teams and to create one version of the truth. This will also ease the documentation of standards and protocols in the BIM execution plan (BEP). The implementation of such technology allows to improve the efficiency of the overall design process, which is often characterized by several step-backs that slow down the process and increase the chances of miscommunication across teams. By creating one version of truth for all information and by enabling collaboration, the process is significantly streamlined and reap the benefits.

Matthé van Baalen
The Netherlands

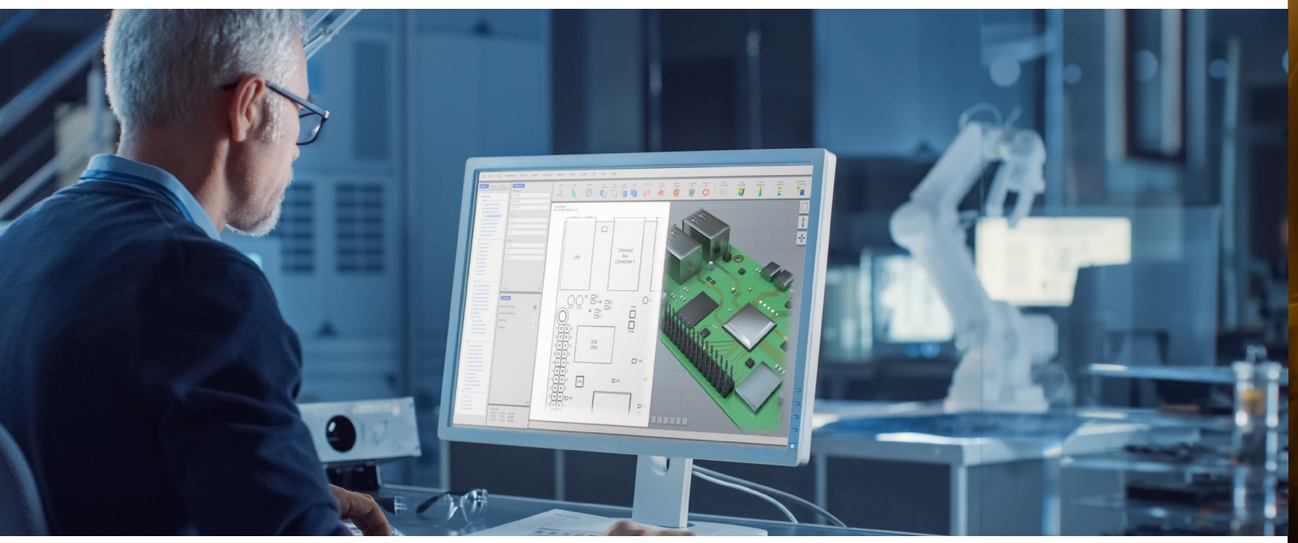
Matthé is the global leader for Design & Engineering at Arcadis. He has worked at the firm for over 25 years and has more than three decades of experience of leading complex engineering projects in multiple locations across the globe. Matthé is passionate about building meaningful relations with clients and delivering exceptional value in an integrated fashion while still ensuring sustainable principles and a perfect symbiosis between the built and natural environments.



The second priority concerns the digitalization of the process, especially through the application of Design Automation. The latter represents a great opportunity not only to increase the efficiency of the process but also to increase the value provided to clients. Indeed, it allows for the generation of multiple design solutions that enable a multi-criteria assessment to identify the optimal solution considering the clients' KPIs ranging from performance, to sustainability, to costs and schedule.

Both of these aforementioned aspects have already and will greatly benefit from Data Analytics and Artificial Intelligence. For instance, when operating in a brownfield environment, it is often necessary to collect data through laser scanning or other techniques in order to develop an accurate representation of the current situation. The point cloud generated by the laser scan can then be converted into a 3D model, and Data Analytics can then be applied to develop advanced insights with regards to asset conditions.

Furthermore, an important aspect to take into account is the current shift in the industry from a 3D-model centric process to a data-centric process. Often, this entails the generation of a project database that contains all relevant information needed to deliver the D&E services. The database then feeds the automated processes and will enable the generation of deliverables such as any visualization in a 3D model, design specifications, design output reports, bill of quantities, etc. This supports both the design process as well as the feedback process as it allows for more effective communications with client over iterations of the design.



The shift towards a data-centric approach also enables more benefits from AI and Data Analytics. Indeed, it is possible to apply AI to the large quantities of data collected with this approach during projects and generate meaningful information about the asset designed and other similar projects. Additionally, it is possible to combine the collected data on design with performance data generated through Failure Mode Effect and Criticality Analysis (FMECA) using AI. In fact, the model is capable of correlating performance to design decision and other project information, in order to predict what could be the consequences of a design decision on crucial aspects relevant to performance (such as safety, availability, and maintainability) and costs (CAPEX and OPEX).

Ultimately, the shift towards an integration of AI and Data Analytics within the D&E phase will continue in the future as the technology becomes essential to operate. All the trends discussed will develop even further, bringing about new opportunities for improvement. For instance, predicting BIM Modelling will be of great support in many projects. The large amount of data collected during the development of a project, such as geological data, topographical surveys, GIS, and restrictions or laws can be fed to AI to support optimization and predictive analytics to recommend changes in the design. The model will not only be able to predict the consequences of a design decision, as has been already mentioned, but also to suggest changes to optimize the current project, given the requirements and restrictions that the asset might be subjected to by the external environment. Additionally, we can also expect an increase in the use of virtual assistants powered by AI throughout the entire design and engineering process, in order to have a constant source of support and real-time information on the asset, the progress of the project, etc. Ultimately, this approach to BIM and D&E will allow to further improve the competitive advantage of a company and provide even better solutions to clients.

CASE STUDY

Tunnel Modeling

The Melbourne Metro Tunnel Project is Melbourne's largest Rail project since the City Loop was constructed in the 1970s. The project involved the construction of five underground railway stations and twin rail tunnels with a combined length of almost 20 km. The deliverable of the project consisted of a detailed lightweight structural model for the full length of the tunnels which would enable interdisciplinary model coordination and drawing production. The client requested that the model be developed with a high level of details so that it is possible to conduct design reviews, extract useful metrics, check clearances, and for other asset management purposes.

To achieve the goals set by the client, traditional manual modelling techniques were impossible to use as they were too labor-intensive, and not able to adapt to design changes as quickly. Moreover, "off-the-shelf" software products available on the market today did not produce the smooth solids needed for drawing production. Therefore, Arcadis developed a model automation script using computational design methods. The script was built using Dynamo for Revit and was designed to place "adaptive components" that contain parameters to control the geometry. While the approach was slower than other workflows, it resulted in a smaller file size and increased efficiency. The script was flexible and allowed for changes to the design to adapt it to other specific locations. This enabled the modelling work to be completed by one individual with the security that the design would conform to the specified parameters. Moreover, it was possible to decrease the time spent on the accuracy assessment process whilst ensuring higher quality for the result.

The final output was a model of approximately 20 km worth of TBM tunnels, cross-passages, and all the associated internal components (such as handrails, walkways, track-forms, etc). By using computational design methods, it was possible to develop such a model with the effort of only one person. If the model had been developed in a traditional manner, it would have been necessary to establish a team of modelers to be able to finish in time while still providing the level of detail required. It was possible to significantly cut down the developing time to 2 days, as compared to approximately 6 to 8 weeks to develop a model manually. Finally, by avoiding the manual aspect of the design and therefore potential errors, the final model was very accurate.

ENVIRONMENTAL RESTORATION

Standardization of data collection, storage and representation in the environmental restoration field has improved significantly over the past three years. With an increased focus on electronic data collection, and data governance, there is an opportunity now to leverage AI and machine learning tools at scale.

While standardization and accessibility have improved, within restoration and municipal maintenance of older assets, there are still decades of relevant data stored in documents that are largely inaccessible without significant effort and cost. To address this challenge, natural language processing (NLP) and machine learning are two technologies especially relevant to digest the information contained within historical documents.

Using a machine learning framework, the accuracy and relevance of the information extracted from historical documents is improving and the overall time and the cost of digesting historical information is plummeting. Once the data are synthesized and cited, technical experts have more time to develop creative solutions for clients instead of laboriously reading hundreds of pages of documents to get to the information that they need. The value delivered for each hour spent will increase because the amount of time spent scouring documents will decrease.

Shawn Burnell
Portland, USA

With 17 years of experience in the industry, Shawn acts as a link between Arcadis' internal technical knowledge networks and our Oil and Gas clients' most challenging problems. He specializes in environmental engineering, including both in situ and ex situ remediation technology design, implementation, optimization and monitoring. He is the Technical Lead in the United States for all of Arcadis major Oil and Gas clients.

AI can also be applied to the operation and maintenance (O&M) of large restoration projects that are often saddled with long term operating costs. Typically, remediation system O&M differs significantly from municipal O&M described above. In the remediation field, cost savings have been achieved by consciously deferring maintenance instead of being proactive about implementation. As a result, most maintenance is done reactively and becomes more costly and much less easy to predict than it could be. Within this application, the digitization of data collection and AI processing of this data have the ability to reduce cost uncertainties in restoration programs which have, for far too long, been viewed as drawn out and expensive with no clear endpoint or resolution.

With effective and efficient storage, retrieval and management of data within environmental restoration projects, data scientists can use AI and cloud technology to provide new differentiating data views and insights to clients in order to generate the value it should for firms and their clients. Here the most relevant technology would be in predictive analytics which couples machine learning and real data to advise project owners on the impact of multiple scenarios, including the potential cost/trend impact of using a particular procurement methodology or contract or certain changes to the conditions. This allows for restoration business clients to achieve better cost predictability and look for year over year savings. It is likely therefore that the advancements in AI that we are already seeing in the asset management and municipal O&M fields will likely be adapted to restoration projects. Furthermore, AI and machine learning will support the generation of predictive maintenance schedules for equipment, ensure compliance, and optimize the restoration dollar spent. The focus will shift from minimizing spend to improving the value of the invested budget. Once the technology is adopted, more standardized pricing will result and the procurement model for restoration services will move more towards unit rates and the focus towards productivity. This is a win-win for the client and contractor. With more widespread applications of AI in restoration projects, the industry holds the promises of higher cost certainty for clients and the contractors get to share in the benefits from increased productivity and higher efficiency.

CASE STUDY

Site summary

Site Summaries are prepared to aid in the strategy development and bidding process for environmental remediation services. They provide details about location, contamination source, site conditions, remedial activities, clean up goals by referring to various historical documents. During a proposal phase for large projects or during the transition of a legacy project, contractors are provided with access to historical documents to review and assess the progress at the site, in order to develop a remedial strategy and estimate associated costs. Technical staff will review the documents and generate a Site Summary consisting of a Microsoft PowerPoint slide deck including both images and text, as well as an executive summary for the technical and management team. This process is usually labor intensive to review all the available documents and can be somewhat subjective based on the experience of the reviewer. Arcadis recognized this as an opportunity to apply advanced machine learning technologies with both image recognition and artificial intelligence to improve the accuracy and response time for the development of a technical approach and costing through automation. This method can also be applied to other areas in the environmental industry with similar document review requirements like due diligence, mergers and acquisitions, and portfolio assessments.

The evaluation of documents prior to automation approach was subject to person's expertise, detailed searches of documents was required, multitude of documents had to be referred, maintaining references for extracted information was tedious, information retrieval was prone to manual errors.

This was a time-consuming activity requiring an average of 20 hours for reviewing documentation and preparing one site summary. The objective of automating the process was to reduce time and effort in document searches, extract most relevant information and ensure standardized site summary generation.

- A knowledge base is created that consists of words, phrases, and sentences that help to answer the key questions in a Site Summary, and to recognize them in their context to replicate the human intelligence. This knowledge base is used to train the NLP model and extract the relevant paragraphs and phrases from the historical documents.
- Keywords and phrases are fed into the knowledge base and its embeddings hit the corpus each time when specific site information is available.
- Using a Deep Learning language architecture (custom word/sentence embeddings using Elmo/BERT) the relevant paragraphs are extracted using the semantic search query mechanism and it is highlighted in the results file.
- It is then passed on to an Entity Recognizer and a QnA module so that the exact answer for a query is retrieved

Two models cater to the overall extraction of the pertinent information: 1) the classification network which segregates all the unwanted information about a site and 2) the embeddings model which extracts the matched results. With the two models, the relevant information is extracted from the historical documents, automatically compiled in a list with associated references, and is used by the technical teams to develop the remedial strategy. By applying NLP to this process, it increases the consistency, reproducibility of the assessment, and results in a 90% reduction of the level of effort.

CASE STUDY

FieldNow

While environmental restoration can greatly benefit from AI, the lack of unified and standardized data collection hampers efforts towards more intelligent decision-making. AI enablement must be integrated from the initial sources of information. FieldNow® is Arcadis' 100% digital data collection and reporting program. It allows for standardized data to be captured in the field and then automatically integrated with analytical and reporting solutions; thereby enabling stakeholders to quickly access and unlock value from the data for more informed decision-making.

Arcadis is a national supplier of remediation services to a large oil and gas client. The range of remediation services, and scale of the portfolio, requires a unified vision of how data is collected, analyzed, and reported. Previously, the data collection methodology was often determined at the site level which resulted in siloed datasets and systems. Experience showed data collected on paper resulted in inefficiencies of time and resources, and occasional data quality gaps. As a trusted key service provider for this client over many years the opportunity to create a deeper relationship using a coherent digital strategy was also identified.

The use of FieldNow® was identified as an approach which could meet the noted challenges. From a management perspective, Arcadis organized a portfolio-level digital team that would plan and implement the FieldNow® approach. This high-level organization for standardizing methodologies of data collection and reporting eliminates the issue of siloed datasets and systems. Both at the portfolio and project level, money was saved by having one standard application for each of the primary field activities, thereby eliminating the inefficiencies of reinventing an existing solution for each project. Data collected using these FieldNow® applications is synced regularly with either cloud-storage databases and/or with hosted internal databases. For internal databases, Arcadis is using SQL Server and Microsoft Azure infrastructure. This centralized data is then used to connect with reporting and analytical software such as SQL Server Reporting Services (SSRS) and Power BI. This allows for decision-makers to have faster access to the data and quickly present the client with reporting or analytic deliverables.

The number of project sites currently utilizing the approach is >300, with more being onboarded weekly. The impact to Arcadis workflows and the client relationship has been significant. Based on the sites actively using the solution, approximately $14 million of revenue has been impacted. Siloed datasets and systems have been reduced from the portfolio work, allowing for Arcadians servicing this client to quickly integrate collected data with reporting and analytical tools like SSRS and Power BI. By using the automated reporting an average of 3 hours is saved for each event report created; at the portfolio level this will result in thousands of hours saved annually. The standardized applications have also resulted in fewer QA/QC hours based on the streamlined data entry and reduction of transcription errors. By using FieldNow® at the portfolio level, and having transparent conversations about the digital transformation, Arcadis has strengthened the relationship with this important client. The gains observed using this approach resulted in Arcadis being identified as uniquely qualified for expansion of services and holds the promises for more future integration of analytics and other AI applications.

About Arcadis and AI

Bram Mommers

Amsterdam, The Netherlands

As Arcadis' Chief Digital Officer, Bram is leading the digital transformation. He has been instrumental in leading the strategy, definition and implementation of many big transformations, enabled by a deep knowledge of our business and the digital context of the construction industry combined with 22 years of industry experience.

Rajiv Sondhi

Arlington, USA

As Arcadis' Chief Technology Officer, Rajiv is instrumental in future-proofing by aligning the business and technology transformation. Rajiv has 20 years of diverse experience in leading technology initiatives across geographies, industries and business domains including varied key leadership roles.

The world is changing and the future will be data driven. As technology continues to develop, our capabilities push the limits of our current realities by enabling processes and results that were once though of as being impossible. If we connect the above listed capabilities, and compound them into advanced technologies, true innovations can be achieved.

At Arcadis, we continuously seek to develop our technical capabilities to better support our clients in tackling complex challenges from improving the quality of life to building communities and supporting the resiliency and sustainability of our societies. We combine fundamental build and natural asset knowledge with our analytics and digital capabilities to bring forward citizen-centric solutions in forms of human-centered design, ecosystem integration, and data services.

In this document, we gathered a collection of Arcadis competencies. We hope it contributes to the digital transformation of our industry. Once we are aware of how to utilize these technical advancements, the opportunities arising are fascinating. By sharing our knowledge about and expectations for the future of the 8 AI technologies – sensory, language processing, perceive, knowledge presentation, learning, decision-making, augmenting creativity, and motion – we hope to inspire just this. These technologies are also shaping and supporting other key project deliverables, including future roles, services and propositions of Arcadis. By responding to this, we will be able to act more accurately to changing and emerging human needs and offer better solutions across all of our service lines.

The AEC industry is one the verge of disruption, and we hope that this code of practice can be a step in the direction towards a more digitized, collaborative, and innovative industry. Which will, ultimately, allows us to offer even better solutions to emerging human needs – and improve the quality of life.

Currently, Arcadis is the leading global Design & Consultancy firm for natural and built assets. Applying our deep market sector insights and collective design, consultancy, engineering, project and management services, we work in partnership with our clients to deliver exceptional and sustainable outcomes throughout the lifecycle of their natural and built assets. We are 27,000 people, active in over 70 countries and generate €3.3 billion in revenue with activities ranging from infrastructure (25%), water (12%), environment (22%), and buildings (41%). We support UN-Habitat with knowledge and expertise to help tackle the challenges of rapidly growing cities around the world.

Today, Arcadis is at the forefront of bringing AI capabilities to the AEC industry. We have delivered more than 150 projects that focus on Data Analytics to our clients. In these projects, our Data Analytics professionals have developed cutting-edge Analytics solutions ranging from descriptive to predictive and prescriptive analytics.

Our key capabilities are:

- **Computer Vision**
- **Design Automation**
- **Optimization and Prescriptive Analytics**
- **Machine Learning**
- **Predictive Maintenance**
- **Robotic Process Automation**
- **Data Engineering**
- **Data Management & Visualization**
- **Natural Language Processing**

Arcadis' technical and domain experts are located around the world, and are looking forward to support you in your AI and Analytics journey.

Background:

Through this guide, we explore what is possible with applying AI today and how the future might look like as a business in the AEC industry.

The core of this document is an emphasis on eight AI technologies, that Arcadis is applying today, that have had and will have major impacts on the industry, but are also shaping and supporting other key project deliverables, including the future roles, services and propositions of Arcadis.

Our technical and subject-matter experts explore these technologies with an eye on the emerging trends which will impact our services, in order to guide and shape the way forward in this paradigm shift, towards a more digitalized, data-driven and collaborative industry to improve the quality of life of places and cities and their citizens.

Acknowledgement:
This document is the result of a collective effort. We would like to truly thank everyone involved who has not yet been mentioned, for bringing this to life!

Bich Dao, Martina Macrelli, Bozhidar Nikolov, Chelsea Renee Valerio, Unai Pascual Muguerza, Claris Parenti, Hedda Svendsen, Coen Wittebrood, Tilottama Chatterjee, Naomi van der Laan, Harsh Rathod, Jernej Vidmar, Yaron Bazaz, Victor Mudretsov, Jason Grandin, Jasper Keij, Mark Parsons, Stuart Roberts, Edward Ashbolt, Tim Shelton, Supriya Murthy, Mike Rose, Sam Manisty, Ryan Miller, Rebecca Hensel, Humberto Hagio, and Monica Dupre.