AI-supported approaches for sustainable urban development

Analysis of case studies

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Content

Image 1: Smart City model, Source: Laremenko, iStock

Executive Summary

Leading tech companies in industrialized countries already deploy artificial intelligence (AI) applications at scale to improve business practices, administration, environmental protection or health services. **But also, for low- and middle-income countries, AI applications offer a range of new opportunities for service providers and governments on all levels.** AI-powered approaches can break down existing barriers to human development and social inclusion and help to achieve the global Sustainable Development Goals in a more efficient manner. Cities worldwide are home to many of the key requirements for AI innovation, including vibrant ecosystems, data sources and infrastructure. Urban areas are thus ideal places to harness the power of AI for sustainable development.

In this study, the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* together with the *Austrian Institute of Technology (AIT)* examine promising, real-world use cases of AI-powered urban development projects in the fields of urban planning, building management, municipal/public finance, mobility, waste management and water/wastewater. **The objective is to showcase what AI can already achieve in urban development today.** Going deeper, for each of these pioneer projects **we provide lessons learnt in terms of the technical framework employed, their approaches to data, risk and project management, followed by a discussion on transferability, cost vs. benefit and critical points that may arise.**

In Ho Chi Minh City, Vietnam, **AI-powered computer vision based on satellite data supports the city authority to monitor changes in land use** to facilitate integrated urban planning processes. In **Peru**, an AI-assisted system that understands text is set up to support the **detection of suspicious money laundering transaction** to secure public budgets. **In Großschönau (Austria) and Vilogia (France)**, an AI-powered system monitors and predicts **energy and electricity consumption in residential buildings** to raise awareness and drive more resource-efficient consumption. In cities all over the world, the *CleanWater AI* can help detect pollutants on a microscopic scale, affordably and in near real-time to improve water supply systems. The *Let's Do It AI* technology can provide cities worldwide with an AI-powered tool to improve their solid waste management operations by **automated garbage detection in public places.** Finally, **in the UK** the *Thames Valley Berkshire Live Labs* illustrates **how AI-powered systems can improve urban mobility and integrated planning and operations** for multiple positive effects on citizen's well-being and the environment.

In the last chapter, we **reflect on the success factors of these projects and lay out recommendations for using AI applications** in contexts of integrated sustainable urban development in low- and middle-income countries.

Artificial Intelligence (AI) for sustainable urban governance and development

Continued rapid urbanisation is one of the most significant and influential megatrends of the 21st Century. While covering only two percent of the earth's land surface, cities across the globe are already home to around 56 per cent of the world's population today. By 2030, they will house two thirds of humanity, rising to more than 70 percent by 2050 (World Bank, 2020: Urban Development Overview).

Cities are growing at a fast pace and increasingly spreading beyond their political and administrative borders. Migratory and commuter movements, flows of capital, resources and commodities as well as soil, air, and water pollution are affecting more and more growing urban areas and their rural surroundings, leading to the emergence of city-regions. Already today, urban agglomerations make up around 80 percent of the global GDP, consume over 60 percent of global energy, produce 70 percent of global waste and emit 70 percent of all greenhouse gas emissions (UN-Habitat, 2016: New Urban Agenda).

At the same time, due to their high population size, density and location, these areas are particularly exposed to the effects of climate change and are also drivers for change and innovation. International agendas such as the 2030 Agenda for Sustainable Development and the Paris Agreement recognise the important role of cities. In fact, two thirds of all Sustainable Development Goals (SDGs) can only be achieved in and with the help of cities.

There is an urgent need for new and improved infrastructures and services due to the extent of urban demands coupled with environmental degeneration and our changing climate. Government institutions, especially at local level, face the challenges of:

- providing a growing urban population with access to basic services and vital resources,
- sustaining continuous economic development and
- managing resource consumption to within the earth's capacity while addressing the challenges of climate change.

In prevailing urban structures, however, resources are managed in isolation by different sectoral departments. This has resulted in inefficient infrastructure systems and land use patterns that fail to utilise economies of scale and waste natural resources. Now more than ever, urban decision-makers are recognising the need for integrated approaches which balance urbanisation, natural resource management and socio-economic development and enable urban-rural interfaces and sectoral inter-dependencies to be managed in a sustainable way. The German Development Cooperation promotes and supports these kinds of integrated urban development processes worldwide, incorporating the four dimensions of inter-sectoral cooperation, multi-stakeholder partnership, spatial integration and multi-level governance.

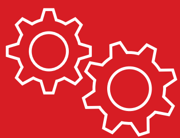
Another megatrend of the 21st century is the rapid digitalisation of all aspects of life as part of the fourth industrial revolution. This revolution is being driven above all by artificial intelligence (AI). It is also supported by other new technologies that have grown out of the IT (or third industrial) revolution. This includes the Internet of Things (IoT), blockchain, robotics, bio- and nanotechnologies and quantum computing. Thanks to increased computing power, breakthroughs in research and an ever-growing pool of data, AI technologies continue to develop at an impressive pace. Large quantities of data, computing power and digital innovation ecosystems are concentrated in cities in particular, alongside the kinds of problems that these technologies can help to solve. As such, cities across the world will have a vital role to play in ensuring sustainable development and human-centric digitalisation.

Cities have become increasingly digitalized over the past decades due to major advancements in digital technologies. At the same time, new methods have been developed that offer detailed insights and opportunities for investigating, planning and managing cities. Cities and their decision-makers (as the closest level of government for citizens) have a great responsibility to ensure digitalization is human centric and develops in the interest of the common good. Digital approaches also open up opportunities for finding answers to climate change and supporting more sustainable development in line with the 2030 Agenda.

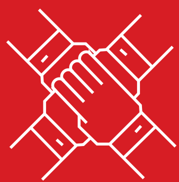
Artificial intelligence (AI) in particular has become increasingly more widespread in cities. From monitoring land use and detecting pollutants in urban environments and infrastructures through predicting household energy consumption and promoting resource efficiency, AI applications open up promising opportunities and can also be used to deal with complex social and environmental interrelationships. However, integrating and intersecting different domains in AI applications is still a challenge. Properly used, AI applications have the potential to make a significant contribution to integrated urban development in future.

For this study, the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* partnered with the Austrian Institute of Technology (AIT) to examine promising, real-world use cases of AI-driven urban development projects in the fields of urban planning, construction, municipal finance, mobility, waste management and water/wastewater. The objective is to showcase what AI can already achieve in urban development today and to find out what lessons can be learned from pioneer projects in terms of management structure, technical requirements and cooperative implementation. For AI to make a positive contribution, it is vitally important that a) AI is used in line with local requirements; b) barriers to entry for the population as a whole as well as research and businesses are lowered; and c) datasets and algorithms are transparent and civil liberties and human rights play a central role. The German Development Cooperation is eager to promote and scale the benefits of AI technologies for good urban governance in order to drive sustainable urban development and help its partners localise Agenda 2030 and the Paris Agreement worldwide. To achieve this, new partnerships and new forms of cooperation and co-creation are needed. This publication is intended to initiate discourse on these partnerships and the accompanying technical and ethical challenges.

Four dimensions of the integrated urban development approach:

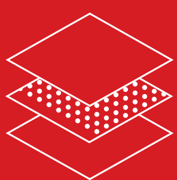


Integration of a variety of strategic urban sectors and services, for instance coupling municipal solid waste management with climate-friendly energy production, or applying a holistic approach to the development of solutions at the interface of energy, mobility, architecture and ICT.



Integration of relevant actors and stakeholders, i.e. supporting not only citizen participation and involvement of civil society organisations, but also bringing together different authorities, experts of different disciplines, actors from the private sector or integrating research institutions into strategic collaborations.

Integration of different spatial areas, i.e. establishing cooperation among neighbouring municipalities, strengthening linkages between urban, peri-urban and rural areas, and creating governance structures at a metropolitan level for intermunicipal coordination and joint delivery of public services such as public transport services.



Integration of different government levels for the implementation of measures to align local activities, strategies and policies with the ones at the regional and national level, to pursue t he dialogue between different government levels in both directions, and finally, to transfer experiences and good practices between government levels for replication and integration in respective policies and plans.

Methodology

For this study, a desk research identified 18 urban AI use cases corresponding to six predefined topics of sustainable urban development. Based on this selection, six use cases were short-listed for in-depth analysis (see table 1 below). This includes interviews with the key project stakeholders.

Selection process and shortlisting

To obtain a general overview of the latest AI implementations in the urban domain, an initial stage of desk research was carried out using the internet, literature and scientific papers in Spring 2020 to identify use cases for each predefined topic of interest (urban planning, finance, building, water/wastewater, waste management, mobility). The selection process was guided by the following principles:

- Project location: Aiming for a wide spread of projects across the world
- Readiness: Aiming for a high level of implementation readiness
- Ability to support SDGs, including:
  - Universality
  - Leaving no one behind
  - Interconnectedness and Indivisibility
  - Inclusiveness
  - Multi-stakeholder partnerships
- Dimensions of an integrated approach towards sustainable urban development, such as:
  - Multi-stakeholder cooperation
  - Inter-sectoral approach
  - Multi-level governance
  - Intercommunal cooperation
- Existing contact with project leaders/experts

Three use cases were identified for each of the six topics. These 18 use cases were then reviewed and evaluated in line with the above principles to identify one use case per topic that could then be shortlisted for in-depth research in the next step.

Interviews

A series of six interviews were conducted with contact persons who were ready to share information on their use case. Each interview followed a semi-structured pattern (see list of questions in Annex B). This approach allowed us to gain insights into the guiding questions complemented by additional information. The interviews were conducted in Spring 2020 via Skype and took one hour. They were recorded and the answers are summarized in the following chapters of this report.

Short-listed urban AI use cases

Topic	Title	Country/Region	Main Partners	Technology
Urban Planning	AI for Earth Land Cover Mapping	Vietnam / Asia	• Ho Chi Minh City • World Bank • Microsoft • Planet • Airbus • VLAB • Singapore-ETH Centre	Satellite image processing
Financing	AI assisted Detection of suspicious Money Laundering Transactions in Peru	Peru / South America	• Financial Investigation Unit (FIU)of Peru • GIZ • Technical University of Peru	Natural language processing
Building	inBetween	Austria, France / Europe	• Austrian Institute of Technology (AIT) • Rina • PUPIN • Acciona • Develco	Convolutional neural network
Water & Wastewater	Clean Water AI		• Clean Water AI	Image processing
Waste Management	Let's Do It AI		• Let's Do It Foundation • Microsoft	Image processing
Mobility	Thames Valley Berkshire Live Labs	Reading, UK / Europe	• O2 / Telefonica • Siemens • WAYRA • Smarter Grid Solutions • Reading Borough Council • Slough Borough Council • University of Reading: • Multiple start-ups	Computer vision

Open Standard	Maturity Level[1]	Contribution to SDGs	2030 Agenda Principles	Integrated Approach
Yes / no	TRL 7 – System prototype demonstrated in an operational environment	• 11: Sustainable Cities and Communities, • 13: Climate Action • 14: Life on Land • 16 Peace, Justice and Strong Institutions	• Universality • Leaving no one behind • Interconnectedness and Indivisibility • Inclusiveness • Multi-stakeholder partnerships	• Multi-stakeholder cooperation • Inter-sectoral approach
No	TRL 7 – System prototype demonstrated in an operational environment	• 16: Peace, Justice and Strong Institutions • 17: Partnership for the Goals	• Universality • Leaving no one behind • Inclusiveness	• Inter-sectoral approach • Multi-level governance
No	TRL 5 – technology demonstrated in a relevant environment	• 7 Affordable Energy • 9: Industry, Innovation and Infrastructure • 11: Sustainable Cities and Communities • 12: Responsible Consumption	• Universality • Leaving no one behind • Inclusiveness • Multi-stakeholder partnerships	• Multi-stakeholder cooperation • Inter-sectoral approach • Inter-communal cooperation
Yes	TRL 6 – Technology demonstrated in a relevant environment	• 3: Good Health and Well-being • 6: Water and Sanitation • 9: Industry, Innovation and Infrastructure • 11: Sustainable Cities and Communities	• Universality • Leaving no one behind • Interconnectedness and Indivisibility • Inclusiveness • Multi-stakeholder partnerships	• Multi-stakeholder cooperation • Inter-sectoral approach • Multi-level governance • Inter-communal cooperation
Yes	TRL 6 – Technology demonstrated in a relevant environment	• 3: Good Health and Well-being • 9: Industry, Innovation and Infrastructure • 11: Sustainable Cities and Communities	• Universality • Leaving no one behind • Interconnectedness and Indivisibility • Inclusiveness • Multi-stakeholder partnerships	• Multi-stakeholder cooperation • Inter-sectoral approach • Multi-level governance • Inter-communal cooperation
Yes	TRL 5 – Technology demonstrated in a relevant environment	• 3: Good Health and Well-being • 7: Affordable and Clean Energy • 9: Industry, Innovation and Infrastructure • 11: Sustainable Cities and Communities	• Leaving no one behind • Interconnectedness and Indivisibility • Inclusiveness • Multi-stakeholder partnerships	• Multi-stakeholder cooperation • Inter-sectoral approach • Multi-level governance • Inter-communal cooperation

Table 1: Shortlisted six use cases depicted in this study background

1 TRL = Technology readiness level

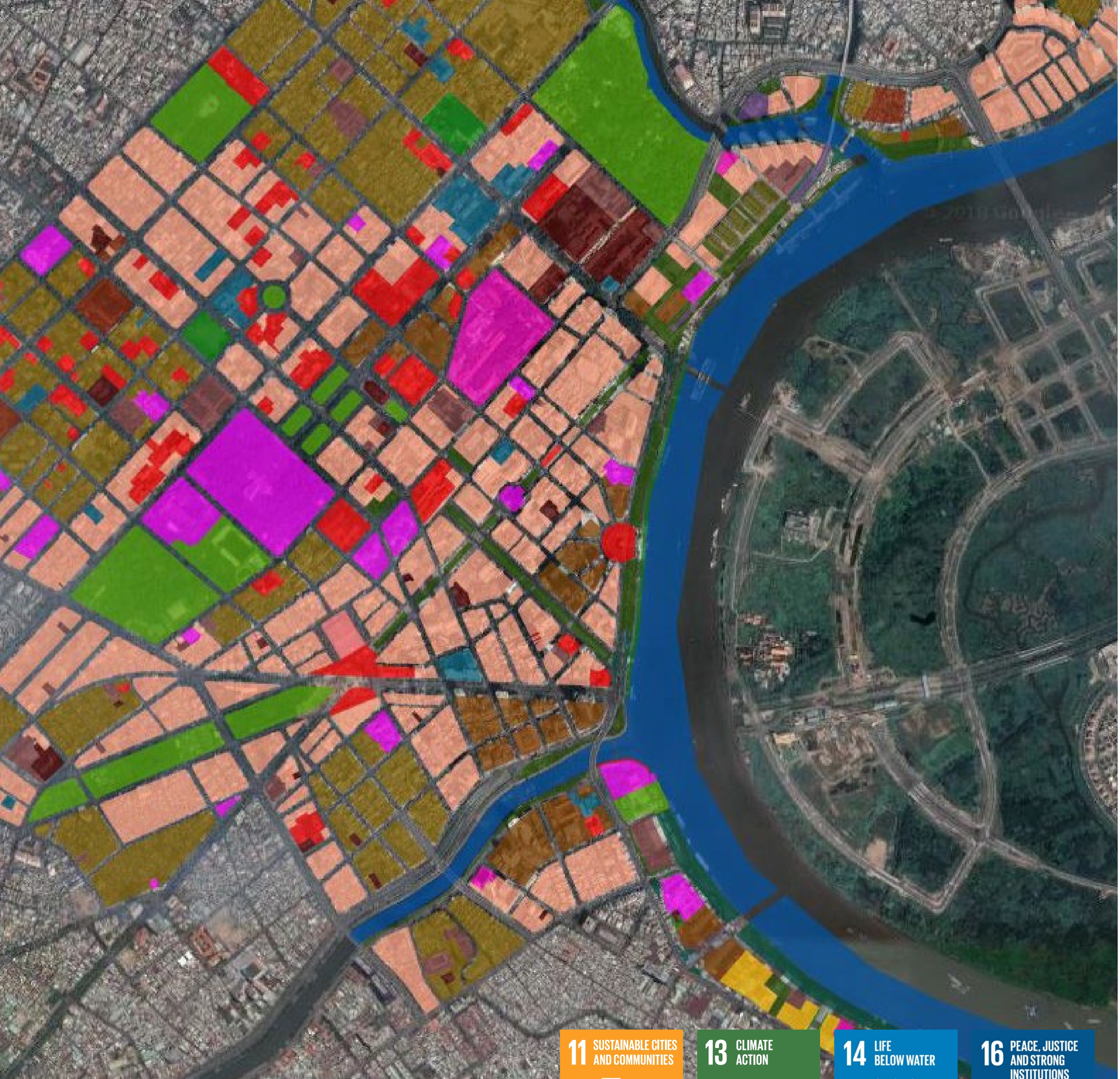


Image 2: Web interface of the AI for Earth Land Cover Mapping tool, Source: Ho Chi Minh City

HIGHLIGHTS

- Online platform that uses AI to monitor changes in land use
- Time-efficient information-gathering process based on satellite imagery
- Bringing stakeholders closer to the local authorities and the city's planning process

AI for Earth Land Cover Mapping – Land use planning in Ho Chi Minh City, Vietnam

Background

AI for Earth Land Cover Mapping is an innovative, user-centric artificial intelligence (AI) tool developed for the Ho Chi Minh City (HCMC) Planning Department in Vietnam. It helps urban planners make decisions aimed at tackling the city's rapidly expanding key challenges related to traffic, infrastructure, environment, uncontrolled investments and new developments. In the past, the city's data and information was fragmented, inaccessible and sometimes outdated. This resulted in a lack of planning cohesion for the city government and its stakeholders. AI for Earth Land Cover Mapping aims to solve this problem.

The HCMC Urban Planning Platform was developed as a first step to help the city face up to its challenges and to help local government take informed spatial planning decisions. The platform increases efficiency levels by digitalizing urban planning processes for the city. It uses remote sensing techniques to detect and classify objects from satellite images. It then vectorises the extracted data and stores it in a way that is accessible to everyone. Users can also provide feedback on the datasets.

The HCMC Urban Planning Platform is currently being enriched using artificial intelligence and deep learning technologies to create an 'AI for Earth Land Cover Mapping tool'. The main goal here is to provide stakeholders with a tool that can be used to interactively classify land cover types from satellite imagery, provide automatic updates and maintenance processes as well as systematically and efficiently update data.

The project is led by the Ho Chi Minh City Planning Department and the World Bank. Further partners include:

- Microsoft AI (company): Technical implementation and delivery of the Microsoft AI tool
- Planet (company): Satellite imagery delivery and tool engineering
- Airbus (company): Satellite imagery delivery
- VLAB (start-up company, Vietnam): Innovative urban planning solutions
- Singapore-ETH Centre (Campus for Research Excellence and Technological Enterprise): Technical work delivery

The platform's AI processes satellite images from different time periods based on the customer's needs and the availability of satellite images. It then delivers detailed information about the land coverage and functionality of an area. Comparisons can be made on an annual, quarterly or monthly basis to monitor changes in the urban footprint, validate claims by the public, approve development requests and prevent uncontrolled urban sprawl and investments that conflict with local legislative policy. This results in a more transparent and efficient exchange of information regarding issues such as permissions, land use coverage, potential environmental risks for an area or current and future developments. This intuitive, user-centric and web-based tool allows public and private stakeholders to interact more closely with local authorities and the city's planning processes.

The project supports the following Sustainable Development Goals (SDGs):

1. SDG 11 “Sustainable Cities and Communities”: By making urbanization more inclusive and sustainable and reducing the adverse effects of natural disasters, for example by reducing buildings’ exposure to flood risk.
2. SDG 13 “Climate Action”: By strengthening resilience to climate-related hazards.
3. SDG 14 “Life on Land”: By focusing on ecology and preserving ecosystems, the project can inform stakeholders about existing ecosystems, the location of forests and degraded land and by doing so, help prevent the uncontrolled destruction of land in Vietnam.
4. SDG 16 “Peace, Justice and Strong Institutions”: By ensuring public access to information and protecting fundamental freedoms.

Implementation

Currently, the project is being developed for the Nhà Bè district in Ho Chi Minh City. The district covers an area of 100 km2 and is home to over 100,000 inhabitants.It is one of the most rapidly developing districts of HCMC. The project’s next step is to find a way to access application programming interfaces (APIs) that will allow authorised users to access data and external software components. This would enable the project organizers to scale up the project for the entire country and combine it with other settings.

Technical framework

Due to the limitations of the lower-resolution Sentinel imagery initially taken from the Google Earth Engine, an independent and automated tool had to be developed to meet the project’s requirements. The AI for Earth Cover Mapping tool is based on a customised deep learning model that uses different kinds of satellite imagery (tested using free low- (Sentinel-2) and medium- (SPOT 6-7) resolution imagery as well as very high resolution imagery subject to a fee (Pleiades 0.5 m)). The technical process can be summarised in following three core parts:

1. A web interface – Developed as an interactive web platform, the interface allows users to directly check their model’s predictions. It also highlights errors. New land use classes can be created and similar areas can be selected on the satellite images to provide new training points for the AI model.
2. A deep learning model – Based on a convolutional neural network (a class mostly applied to analyse visual imagery), the model uses unsupervised feature-learning on satellite images without labelled data for initial training. It allows elements that belong to different categories to be identified, including infrastructure networks, natural objects (such as rivers and lakes) and buildings. It can also detect if their colours, textures and patterns change.
3. Satellite images – The platform can be used for both visualisation and classification purposes. It is does not depend on a specific source of satellite images or their resolution (it is also not limited to RGB channels). While higher-resolution images enable more details to be detected in land cover analysis, they also take more time to display and are more expensive to obtain. According to the project officer a model that is run on 0.5 m resolution imagery will take nine times longer to classify than a model run on 1.5 m resolution imagery. It should be noted that in the case of HCMC, the local climate conditions (for example the rainy season in the HCMC area) can have a major impact on the quality of the imagery gathered.

Data management

Personal data is not used at any stage in the project. The high-resolution satellite imagery is currently provided by Planet and Airbus, and data outlines that make commercial imagery accessible must be provided. The images are not collected in tiles but are captured based on the geographical boundary of the region in question. Images must be completely cloud-free.

Data is stored in the cloud. This means that there is no need for the local authority to store the imagery on a separate web server. This reflects the project’s aim to deliver a service that always uses the latest available satellite images. Currently, the team is also developing a set of APIs that will allow the project to be scaled up to cover the whole of Vietnam.

Risk management

Depending on the climatological conditions of the area in focus, for example if it is the rainy season in Ho Chi Minh City, there is a technical risk that images may take longer to be created. It took a month, for example, to collect a previous set of images from the rainy season. However, this risk should not be borne by a local government, which means that the standards for imagery delivered by a satellite company must be defined beforehand. Base images that cost an estimated price of €100, for example, should be less than six months old and have less than five percent cloud coverage.

In terms of usage and in light of the many different stakeholders involved, there is also a risk of the method being misused to benefit parties involved in the project, such as real estate developers. The involvement of an external partner – in this instance the World Bank – helps minimize this risk and ensure the approach remains independent.

Governance & project management

The project is organized in a top-down structure between the city government, technology companies, start-ups and academia. Ho Chi Minh City and the World Bank are the project leaders of the *AI for Earth Land Cover mapping* project. They meet on a weekly basis with the key partners Microsoft AI, Planet and Airbus plus representatives from three HCMC departments (the Department of Planning and Architecture, the Department of Transportation and the Department of Construction) to define the next steps. The chairman of the political party is updated quarterly or every six months.

Subsequent use

Setting clear and realistic expectations on how AI technology can help in a specific area of interest such as urban planning is one of the key criteria for the success of the Ho Chi Minh use case. For the HCMC use case, artificial intelligence and disruptive technologies in general are characterised by three dimensions – capability, complexity and cost:

1. Capability – Results do not have to be perfect, but they should be 'good enough'. Instead of spending years producing a topographic land use classification map, AI technology can deliver results in a much shorter time and as a scalable product. The ability to overlay a regional border is also very important as this allows data to be displayed by area and not by imagery tile[2] . Being able to export information for two different time periods is another key factor as it allows users to compare them and see if there has been a change in land use.
2. Complexity – Even the most sophisticated AI model will not be of any use if it does not come with a simple user interface or documentation.
3. Costs – An affordable technology infrastructure is the key to success. In this case, for example, the resources are provided by Microsoft AI. A transparent overview of costs and knowing the total cost per satellite imagery for the time period in question are equally important.

Transferability

The AI for Earth Land Cover Mapping project is characterised by its scalability. Developed initially for one district of HCMC, plans are already underway to expand it for all of Vietnam. Later on, it will be possible to reproduce the project in other places around the world because it uses Microsoft AI and Sentinel satellite tiles. In the case of densely populated areas such as HCMC, however, georeferenced data with a higher granularity than Sentinel might be needed. This will have to be evaluated beforehand.

Besides the technological innovation itself, public and procedural engagement are crucial elements to the overall success of the approach. This includes factors such as the legal framework for data sharing and access practises that might differ from country to country.

Cost benefit & business model

As the project is still in its development stage, the cost calculation has not yet been finalized. Based on ongoing development and findings, however, costs will be closely linked to the chosen setting and quality of the images. While lower-resolution imagery is available for free (and suitable for rural and less dense urbanised areas), high-resolution imagery is subject to a fee.

The project is scalable and provides several benefits to users that clearly exceed the overall project costs. These can be summarized as follows:

1. Improved monitoring – Gathering information and exposing urban changes such as the growth of the city's urban footprint or changes in land use patterns.
2. Improved management – Addressing and detecting issues such as informal land growth, buildings' exposure to environmental risks and green areas that have been replaced by new, unplanned developments.
3. Informed decision making – Taking informed action, such as adapting tax administration or establishing measures to prevent environmental risks.

Combining additional information such as tax administration information with the satellite imagery will enable the model to be expanded to other domains outside of planning. This will allow it to be used by authorities, for example, to determine the number of staff they will need in future.

The final goal is to create a user-friendly tool that provides a large amount of information in a less complex way. The sustainable business model is based on an annual subscription, which will reduce costs and make it more affordable and accessible for local authorities. As accessibility to useful satellite images is key to the tool's sustainability and long-term success, supply agreements between image providers and governments will be established.

Critical perspective

- Transparency – While the existing Urban Planning Platform is mostly citizen-centred, the *AI for Earth Cover Mapping* tool is built primarily to enable local government and the planning department to make informed decisions. Giving users access to land use coverage information means that it will be possible to create overlays showing additional information. This will enable feedback loops and also increase the chances of attracting more investors to HCMC by making information more transparent, with English translations for international investors.
- Technological independence – Although the national government has access to high-resolution imagery, local government does not. The World Bank and HCMC are working together on this simple-to-use AI tool to help tackle this ongoing challenge. Allowing stakeholders to own the application will put pressure on central government to demand higher resolution images: Initially by implementing free imagery to show the potential of the application, and then by using better, more expensive imagery with a higher resolution.
- Environment – *The AI for Earth Cover Mapping* project focuses primarily on flood risk as the tool's main aim is to control areas that are or could be affected by floods.
- Political interests – It is crucial that the benefits and value of the project are interesting at a political level and not just in terms of monetary value but also politically. Hence, its outcome and resulting decisions are of political interest.

2 An imagery tile is a satellite image that is part of a bigger satellite image tile set. The bigger set of image tiles is taken by satellites in a row in order to cover a larger area of the earth and achieve the highest resolution possible. Satellite images are usually sold as individual tiles.

Image 3: Animated AI supported grafical user interface, Source: Metamorworks, iStock

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

17 PARTNERSHIPS FOR THE GOALS

HIGHLIGHTS

- Structuring of unstructured STR information to improve detection of illegal financial transactions by using AI
- AI text processing methodology
- Sorting suspicious transactions based on structuring and prioritisation to assist human analysts in financial authorities and to streamline and increase the efficiency of transaction processing

AI-assisted detection of suspicious money laundering transactions in Peru

Background

Tracking and detecting illegal income is a massive challenge all over the world, but especially in developing countries. Any money transactions that raises the suspicion of being made to hide or launder the proceeds of crime must be reported. This includes transactions for buying a house, withdrawing larger amounts of money or exchanging currencies. Banks, notaries, lawyers and other reporting entities are obliged to share their suspicious transaction reports with so-called financial intelligence units (FIUs). Currently, these reports are processed and analysed manually by employees of the FIUs. Another aspect is that investments in cities that are driven by money-laundering considerations rather than economic considerations would decrease (distorts prices for real estate and urban planning).

In Peru, suspicious transaction reports (STRs) are addressed to the country's Financial Investigation Unit (FIU). The FIU staff has to read the reports, analyse and prioritize them. Cases representing a potential crime are sent to the prosecutor's office. The number of these STRs is continually increasing, for example from around 2,000 in 2011 to over 15,000 reports in 2018. This means that the FIU has limited staff to process the growing number of STRs. It is assumed that an AI-assisted process could improve the FIU's capacity to analyse reports. It would also enable the FIU to cope with an even higher number of STRs in future. The objective of the project is to develop an AI-based assistance system that allows the FIU to structure unstructured information from the STRs.

This project primarily supports two Sustainable Development Goals (SDGs):

1. SDG 16 "Peace, Justice and Strong Institutions" – Peru is one of the three biggest coca plant cultivating countries. The majority of the coca is used by cartels to manufacture drugs, and the income generated from this business is laundered via various channels. AI will enable the FIU to detect these more efficiently.
2. SDG 17 "Partnerships for the Goals" – The project will improve the country's domestic capacity for collecting taxes, enabling it to strengthen its financial resources for development projects. The FIU can share knowledge with comparable units in other countries.

Implementation

Technical framework

The project started in 2019 and will finish in 2021. It is important to mention the participation of the academy in the realization of the project. The technical knowledge about AI was incorporated into the project by contracting the Research Institute of the Technical University of Peru to provide the service of designing and implementing the AI model for the identification of the relevant data extracted from the STR. A natural language processing method has been applied to perform unstructured information processing to facilitate further analysis and prioritization of the STRs. The technical implementation was led by the Technical University of Peru and involved two AI scientists. Labelled datasets had to be created to train the machine learning models. This first step was carried out by humans, who classified raw textual data that enabled the AI algorithm to automatically learn how to identify new information. Manually labelling the training dataset took over three months. As a project partner, GIZ provided technical support and assistance for dataset labelling and hired two consultants with experience in machine learning who supported the technical development. As most of the STRs have unstructured text data, machine learning methods were used to process the data and obtain useful information. A recurrent neural network was applied for natural language processing (NLP) using an attention mechanism – in particular, Tensorflow and Genism python packages – and the Spanish word2vec representation of the Spanish vocabulary was used.

Data management

According to anti-money laundering standards, many institutions and economic stakeholders are required to report suspicious transactions to the FIU. The list of reporting entities includes banks, car dealers, real estate companies, currency exchange offices and notaries, all of whom use different criteria to classify transactions as suspicious. When a suspicious transaction is detected, they complete the above-mentioned suspicious transaction report (STR). This includes a manually written section that describes the details of the transaction and the reason why the reporting entity suspected an illegal act. The STRs are then transmitted to the FIU, where employees read them and decide on the level/priority of suspicion. In the event of strong suspicion, employees elaborate a financial intelligence report ad forward the case to prosecution. All data is highly confidential and only FIU and state institutions have access to it.

Risk management

STRs contain extremely sensitive information about the individuals involved in the transaction and so they are treated in a highly confidential way: STR datasets are only available on computers inside the FIU office and these are physically disconnected from the internet. Each developer works in this office and is not allowed to copy any data to an external storage device. A polygraph test is performed on everyone twice a year to prevent any sensitive information from the FIU being leaked.

Governance and project management

Working as technology partners, GIZ and the Technical University of Peru developed the AI for the Financial Investigation Unit (FIU). The FIU employees must be trained to use this system. During an initial phase, the university researchers provided low-cost support to the FIU operators. Once the initiation phase is over and the project has been concluded, the management and governance of the tool will be handed over to the FIU.

Subsequent use

Transferability

Based on international standards, most countries worldwide have similar processes for reporting suspicious money flows. The text processing system embedded in this project can be directly transferred to other Spanish-speaking countries and adjusted to any local language in non-Spanish-speaking countries. The system might have to be retrained for non-Spanish-speaking regions. The resulting increase in tax income can be used by cities to fund urban development projects, make them more sustainable and improve quality of life. It could also be used to expand local/municipal revenue management.

Cost-benefit & business model

The material costs of the project were under €10,000. This included the purchase of two computers with strong graphics cards (for training NLP models). The cost of designing and implementing the AI model was under €25,000. This low amount was due to the fact that the Research Institute of the Technical University of Peru is a non-profit agency, which allowed the establishment of a cooperative relationship between public actors (University and FIU) with the technical assistance of the German Cooperation. The AI-supported system described here improves efficiency and accuracy by automating the scanning of STRs and reducing the amount of human labour required for this process.

Critical perspective

- The project shown here is still in the development phase. The first prototype of the system is scheduled to be ready in beginning of 2021 and will be tested afterwards. The proof of concept can only be evaluated during 2021. The sensitivity and accuracy of this system can only be evaluated when there is an existing prototype, and the viability of the proposed procedure can only be determined based on these performance indicators.
- The STR documents are highly confidential. The risk of potential leaks is high as the method of questioning employees using a polygraph is not 100 percent reliable.

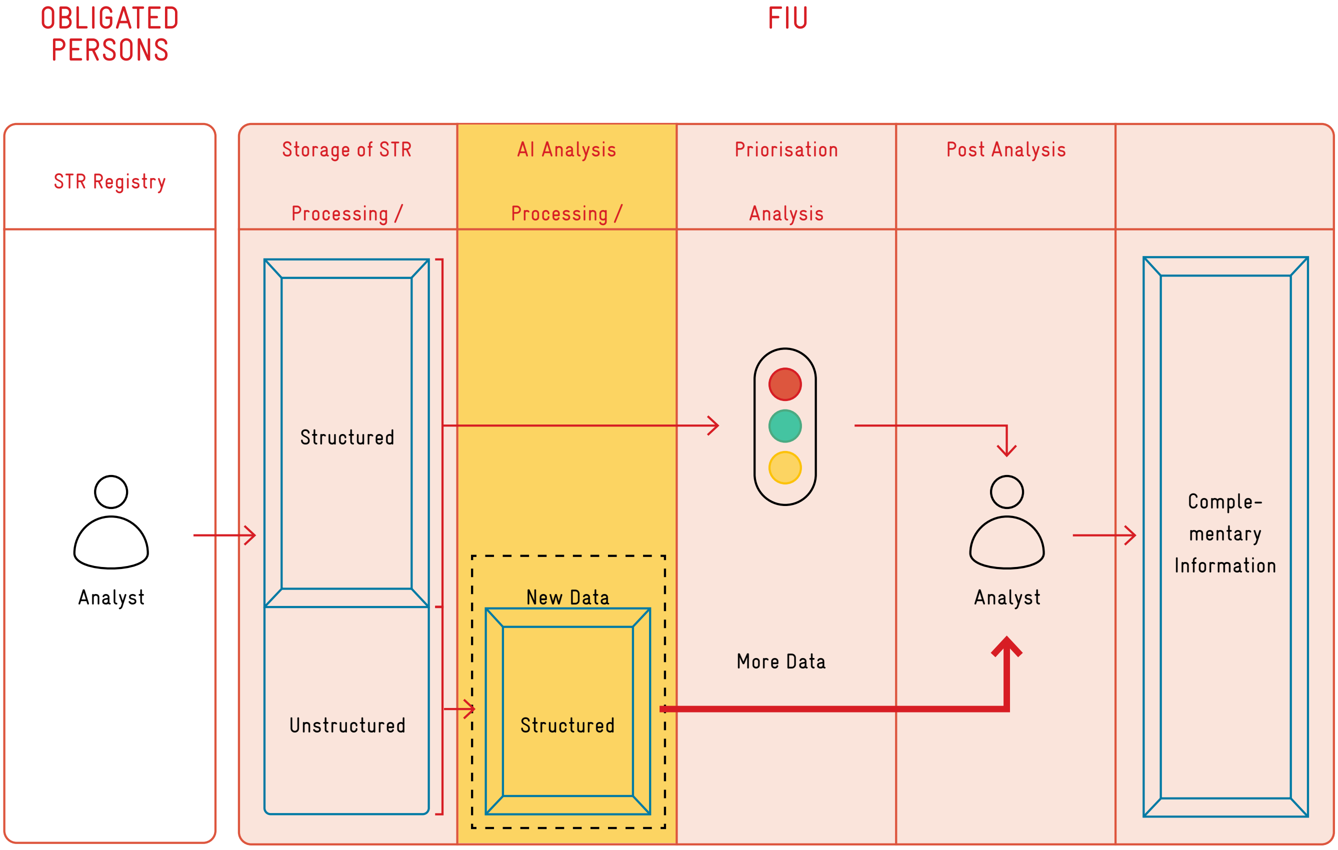


Image 4: Proposed scheme for the treatment of suspicious financial transactions, Source: FIU & GIZ Peru

Image 5: Smart Home animation, Source AH Fotobox, iStock

HIGHLIGHTS

- Using AI to monitor and predict energy and electricity consumption in residential buildings.
- An automatic data collecting system can be installed in any building, whether a new build or older property.
- Inhabitants are informed of their electricity consumption, raising their awareness and prompting them to implement energy-saving measures.
- Provides a consumption prediction for electricity grid providers.
- Detects failures in building installations as well as heating, ventilation and air conditioning (HVAC) systems.

inBetween – Monitoring, analysing & nudging towards energy efficiency

Background

Nowadays, we spend more than 80 percent of our lives within buildings. At the same time, households represent around 30 percent of the total energy consumption, with electricity consumption often higher than necessary. Making residents aware of this by analysing their consumption patterns and providing them with feedback therefore has the potential to generate significant energy savings: Informing electricity users about their energy consumption can trigger important psychological processes that can cause people to adjust their lifestyle and consumption preferences[3] (for example by using energy-efficient vacuum cleaners or efficient light-emitting diodes (LEDs) instead of light bulbs, turning off espresso machines when not in use or using an eco-program on the washing machine).

At the same time, from an operator's perspective, predicting electricity consumption is a vital for operating smart grids, especially when power is drawn from renewable power plants that are highly dependent on the weather. Thanks to recent developments in IoT (Internet of Things) devices and the current state of data processing technologies, we can now precisely monitor and analyse electricity consumption and predict electrical energy consumption using state of the art data-mining methods.

The name of the *inBetween* project is an acronym for "ICT-enabled BEhavioral change ToWards Energy EfficieNt lifestyles". It was funded by the European Horizon 2020 fund and focused on how to use information technology to investigate energy-efficient residential lifestyles. The project monitored and analysed energy consumption behaviour inside residential buildings and predicted possible energy use as well as energy-saving potential. According to the project report, "*the main motivation for such development is that more than 30% of the world's electricity can be attributed to the residential and commercial buildings* […] *this figure can be reduced by up to 12% by only giving feedback to the customers on ways in which they consume their energy on an appliance level.*"[4]

Project partners included:

- AIT Austrian Institute of Technology (research and technology organization responsible for data mining and evaluation)
- Rina (private company responsible for integrating middleware, platform architecture and project coordination)
- PUPIN (R&D institute responsible for mobile application deployment and middleware)

3 For an literature overview see: Dosmukhambetova, D. (2020). The use of behavioural insights in promoting residential energy efficiency: an overview of available literature. [Auckland Council technical report, TR2020/015]

4 Cited from *inBetween*'s non-public 1st Period Project Report. A summary of this internal project report can be found on the [EC's Cordis website]

- Acciona (private company responsible for developing the visualization platform)
- Develco (private IoT company that develops smart home devices and sensors: smart meters, smart cables, motion sensors, window sensors and volatile organic compound (VOC) sensors).

The AIT Austrian Institute of Technology was responsible for evaluating data from smart electricity meters and sensors. Together with the project partners, the institute set up a database to store sensor data collected at 15-minute intervals. The AIT team mined the sensor data gathered and developed machine learning models to classify usage patterns and predict electricity consumption.

The project supports the following Sustainable Development Goals (SDGs):

1. SDG 7 "Affordable and Clean Energy": This project aims to make households more energy efficient.
2. SDG 9 "Industry, Innovation and Infrastructure": Enhancing technology and access to information for improved services and infrastructure.
3. SDG 11 "Sustainable Cities and Communities": The project promotes sustainable urbanisation and reduces costs for basic services.
4. SDG 12 "Responsible Consumption": The project promotes the development of technology that makes building residents aware of their exact electricity consumption, and thus contributes to the more responsible consumption of energy resources.

Implementation

The project was implemented in two residential districts – one in Großschönau, Austria and one in Vilogia, France.

Technical framework

The development of the project can be broken down into following three main topics:

1. Data – Multiple IoT sensors were placed in individual apartments inside the residential buildings. These sensors were used to collect the requisite data (including temperature, humidity, air quality, door and window sensors, energy meter data) every 15 minutes with a granularity level based on the findings of preliminary data analysis. Publicly available weather data was also used together with proprietary data on individual apartments, which was collected over a three-year period and stored in a secured database.
2. Clustering – Data clusters of consumption profiles were defined based on the time series. These were then used to categorize consumers. This step allowed more accurate forecasting techniques to be applied based on classical machine learning algorithms. The user profiling service is used to bundle users (apartment occupants, occupants of public/office buildings) and their consumption behaviour into groups. To do this, the clustering algorithm was initially developed using publicly available household data as well as Birch and K-means clustering algorithms.
3. Correlation analysis – In a next step, the defined clusters were correlated with variables based on environmental (weather), social (number of occupants), financial (electricity prices) and temporal (calendar) characteristics and the outcome was included in the profile categorization. This allows the operator (energy manager/energy advisor) to understand consumption and generate recommendations targeted at specific user groups.

The project uses various Python packages for analysis purposes. Specifically, Python implementations of the scikit-learn package and other Python packages (for example, pandas for handling time-series data) are used for the supervised and unsupervised learning algorithms.

With regard to forecasting time series, the Python analysis packages (pandas, NumPy etc.) were implemented to create features for testing various regression algorithms (support vector machines, ElasticNet, kernel ridge regression). A cross-validation approach was used to tune the hyperparameters. The resulting prediction model was delivered as a Python package and deployed on a prediction server, which allows the prediction process to be triggered on demand.

On the application development end, a consumption data analytics module based on a convolutional neural network was implemented for disaggregating electricity loads (as a special task for non-intrusive load monitoring (NILM)) together with an alarming system that instantly reports operational building failures to facility managers. This allows facility managers to recognize and rapidly resolve failures that could otherwise result in serious and costly damage if left undetected.

Furthermore, to make the solution more transferrable and generalized, an ontology was developed as a dictionary of metadata fitted to the building information modelling.

Data management

Smart sensors were installed in apartments and data was collected in 15-minute intervals. All of this data was stored in a central database that could be accessed by the project partners.

The data sharing agreement between the residents and the companies had to comply with the European General Data Protection Regulation (GDPR) framework. This gave the individuals the option to opt out at any time and also ensured that their data was kept securely. Besides this, a standard level of data management for exchanging, accessing, managing and integrating data was used. The development of personal data handling processes slowed down the development process.

Risk management

To ensure the project complied with the privacy requirements of GDPR, the data was actively anonymised before being stored. For mitigation of data privacy risks, governance approaches for data access rights were discussed with residents and later developed.

Governance & project management

To ensure data was handled appropriately, a partner deployed a local compute server instead of a cloud solution. The safeguards for data safety included authentication methods, passwords and the removal of personal data in the pseudo-anonymised dataset. The residents had access rights to their own consumption data in the mobile app.

Subsequent use

Transferability

The monitoring and prediction system built for this project is flexible and can be easily transferred to other residential and commercial buildings worldwide. The system can be installed in new builds and older buildings, and the requisite sensors can be installed in apartments. They do not have to be installed in all apartments. If inhabitants do not agree for privacy reasons, their apartments can be excluded. This may lead to challenges with regard to acceptance in different cultures: Austria and France, for example, are two highly developed countries. These tech-affine cultures offer excellent conditions for this kind of application. Acceptance levels in emerging and developing countries, however, might be lower due to different cultural backgrounds. This needs to be investigated further.

Potential stakeholders in the results of the project include:

- Technology providers for smart home devices and home automation systems
- Governments and policymakers: The vast amount of real data will enable them to make better decisions
- Social housing associations: These organizations are keen to minimize costs and spending on resources and also want to promote energy-saving measures
- Energy service companies: These organization are interested in managing energy consumption more effectively and flattening load profiles

The data collected for the AI application belongs to the people it was collected from (in accordance with GDPR requirements). As a result, residents have full access rights and the ability to opt out or have their data deleted at any time. Furthermore, the` users were given an option to receive insights into the results generated by the AI. This included consumption forecasts and detailed improvement recommendations on safety and energy efficiency. This further created the requirement to safely disaggregate the anonymously labelled datasets.

In this project, AIT administered the AI and smart applications though the Docker containers. The hardware and sensor network system were installed and designed by the partner companies.

Cost benefit & business model

The costs and exact specifications of the sensors are confidential. However, if we consider the continued global trend towards low-budget IoT devices and DIY, we can assume that costs can be kept at a minimum. The project results provide multiple benefits:

- Providing feedback to residents about their exact consumption tends to lead to more efficient consumption.
- Continuously monitoring electricity consumption and detecting faults in electric appliances leads to lower building/facility maintenance costs.
- Predicting the electricity consumption of buildings and districts provides huge benefits to electricity grid operators as it enables them to more effectively adjust energy production at power plants.

Critical perspective

- Data privacy – The incorrect implementation of data privacy and encryption measures could lead to the potential misuse of electricity usage data
- Efficiency – Statistical data would not provide many benefits in apartments where electricity use is already very low (for example in apartments where there are only a few electrical devices or where the inhabitants already use highly efficient appliances). The cost of installation and the benefits from potential energy savings should therefore be evaluated. Here, we would suggest pre-screening apartments to ensure maximum effectiveness.
- Framework/environmental conditions – The system described here is viable in places and municipalities where there are existing, stable internet networks as well as facility management services and existing expertise for installing the devices.
- Efficiency assessment – Long-term data collection and evaluation would be required to assess the exact consumption reductions that could be achieved with this system. This information is currently not available.
- Resident engagement – Residents must be interested in saving energy. France and Austria, for example, might be different to countries with emerging middle classes who may not care as much about the environment.
- Nudging – As mentioned above, the project was implemented in two highly developed western countries with high levels of cultural acceptance for technological innovations. In these environments, changes in behaviour and nudging strategies aimed at saving energy are built on existing, familiar cultural conditions. Different approaches may be required for different parts of the world, for example in emerging or developing countries, as each society has its own, individual culture. Therefore, a preparatory step such as a workshop is needed to define the nudging strategies that would work best with specific cultural habits and norms.

Image 6: Wastewater treatment plant, Source: Ivan Bandura, Unsplash

3 GOOD HEALTH AND WELL-BEING
6 CLEAN WATER AND SANITATION
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
11 SUSTAINABLE CITIES AND COMMUNITIES

HIGHLIGHTS

- Fully automated pollutant detection using inexpensive IoT devices and AI software
- Possibility of continuous, large-scale and near real-time monitoring of water supply systems where purification is not (yet) available
- Source code available as open source

Clean Water AI – Automated water quality analysis

Background

The idea behind *Clean Water AI* was to provide cities with an inexpensive, easy-to-install and easy-to-maintain means of automatically monitoring their existing water networks.

Most cities in developed countries purify their water by injecting chlorine into their water systems. This process is expensive to run and maintain, and most cities in developing countries cannot afford to have a chlorine-based water purification system. Furthermore, the traditional method of monitoring a water system, even in developed countries, involves using an analysis strip that indicates chemical and biological contaminants in water. These strips have to be analysed by maintenance staff. It is a costly and relatively slow process as the individuals have to travel to the different water supplies to carry out testing. Deployed on a large scale with lots of devices, *Clean Water AI* can be used to monitor water supply systems in near real time, identifying contaminants in minutes. The monitoring system can also be run remotely by a small number of people.

First of all, the IoT device collects a water sample and lets any potential bacteria grow. It then analyses the water quality for dangerous bacteria and harmful particles. The result is then stored in cloud storage and can be visualised, for example, on a dashboard. A dedicated dashboard still needs to be developed. Alternatively, end users can use an existing dashboard and connect this to the cloud storage.

The solution was developed after the CEO of *Clean Water AI* visited countries and cities where water supplies were of a poor quality. He decided he wanted to find a way to improve the situation. His analysis of countries capable of implementing the solution revealed that China was a good candidate as the water supply and purification systems used in the country's cities were often poor. At the same time, China has the money and means to implement smart city solutions quite easily. He obtained a letter of intent from the City of Hangzhou. Due to the coronavirus situation, however, plans to further implement the project have come to a halt. The concept involved determining the quality of water in drinking fountains in places such as schools and hospitals. This would have been done by checking the quality of water coming from existing water filters and would have enabled public utility companies to use *Clean Water AI* as a tool for assessing the effectiveness of these filters.

Clean Water AI is a proof of concept and the software works. As an AI-based solution, it provides the added value of being an automated, near real-time monitoring facility which can be easily installed and maintained by cities. It is a primary classification tool that lets a water inspector decide whether they need to go to the specific node in their water supply system and look for the cause of contamination (for instance, a broken toilet that is leaking into the surrounding water pipes).

Clean Water AI is an independent start-up comprising two people who developed the project from idea to implementation in half a year with €170,000 of implementation costs. The estimated unit costs for one device is €50 to €60. Currently, the project has been delayed due to COVID-19 and trade restrictions between the U.S. and parts of the Middle and Far East.

The project supports the following Sustainable Development Goals (SDGs):

1. SDG 3 "Good Health and Well-being": By improving public health through safer and cleaner environmental conditions.
2. SDG 6 "Water and Sanitation": By improving water quality and reducing pollution.
3. SDG 9 "Industry, Innovation and Infrastructure": By developing high-quality, reliable and resilient infrastructures through enhanced technology and access to information.
4. SDG 11 "Sustainable Cities and Communities": By ensuring access to sustainable basic services.

Implementation

Technical framework

First, a requirements analysis was created and the AI was then developed accordingly. The AI uses a self-developed convolutional neural network (CNN) and computer vision on a microscopic camera as an optical solution for detecting dangerous particles and bacteria in water. It works in almost the same way as security camera (CCTV) footage.

The development and setup can be summarized in following steps:

1. Water flows underneath the camera. Particles and bacteria are scanned by the lens and recorded for real-time analysis by the CNN.
2. In the initial developing steps, the project prototype used a laptop computer with a neural computing stick connected to a microscopic camera.
3. In the next iteration, the solution was developed as an IoT device. In its current state, *Clean Water AI* is as self-containing device (the size of a shoebox) that can be easily installed in areas where monitoring is required.

Supervised learning, a subfield of machine learning, was used for image classification. Two existing open-source models, CaffeNet and Mobilnet, were used in the development of the system and software libraries. Tensorflow and caffe were used to train the model. The company mobilized the expertise required to develop the AI application locally and a Titan RTX was used to ensure sufficient computing power. The deep learning neural network enables users of *Clean Water AI* to analyse water contamination in near real time based on the shape of bacteria at microscopic level. If new bacteria types need to be detected, the CNN can be trained and automatically updated.

Data management

This project uses data gathered by monitoring water systems (for example, videos and images of water) from utilities such as water management and treatment companies, or from city governments. As long as only water data and no personal data is required, there are no legal or privacy (GDPR) issues. In addition to this, there is no need for an agreement or framework on data sharing provided the data is not shared with third parties by Clear Water AI and is handled and managed by the client. The client, for example a city's municipal administration department, may decide to make aggregated data publicly available, or just use them internally for maintenance purposes only.

Risk management

Clean Water AI covers a niche area between cities with none to very little developed water monitoring in place and smart cities that run a (modern) water monitoring system. It can detect leaks in sewage systems (enabling operators to quickly shut-off of a branch in the system, for example), it cannot purify the water itself. The developer of *Clean Water AI* considers most of China to be an appropriate market for the application. China has both the political will to introduce new technologies and the budget to buy the devices. At the same time, Chinese infrastructure is often too large (in some regions) to introduce chlorine purification, so the *Clean Water AI* application would close the gap until a nationwide introduction of chlorine purification is possible, i.e. the monitoring can be used as an early warning system to indicate water contamination and protect water consumers of an area or within a building.

Governance & project management

The system is integrated in the existing client's technical infrastructure and used constantly to monitor the water quality within the network. In terms of maintenance, the system health of the IoT camera devices can be monitored automatically. The *Clean Water AI* software can be maintained by the company on a contractual basis.

Subsequent use

Transferability

The application example can be transferred to other contexts such as developing and emerging countries. The most important aspects here include a city's ability to invest in the technology and the presence of a functioning or possibility to install a water purification system that will work more seamlessly with *Clean Water AI* in future. The AI solution is not a viable option for cities and regions that do not have any purification system in place as the software only monitors water quality, it cannot improve it.

Cost benefit & business model

The project's ability to automatically monitor water quality in near real time is a key factor of its success. As part of its business

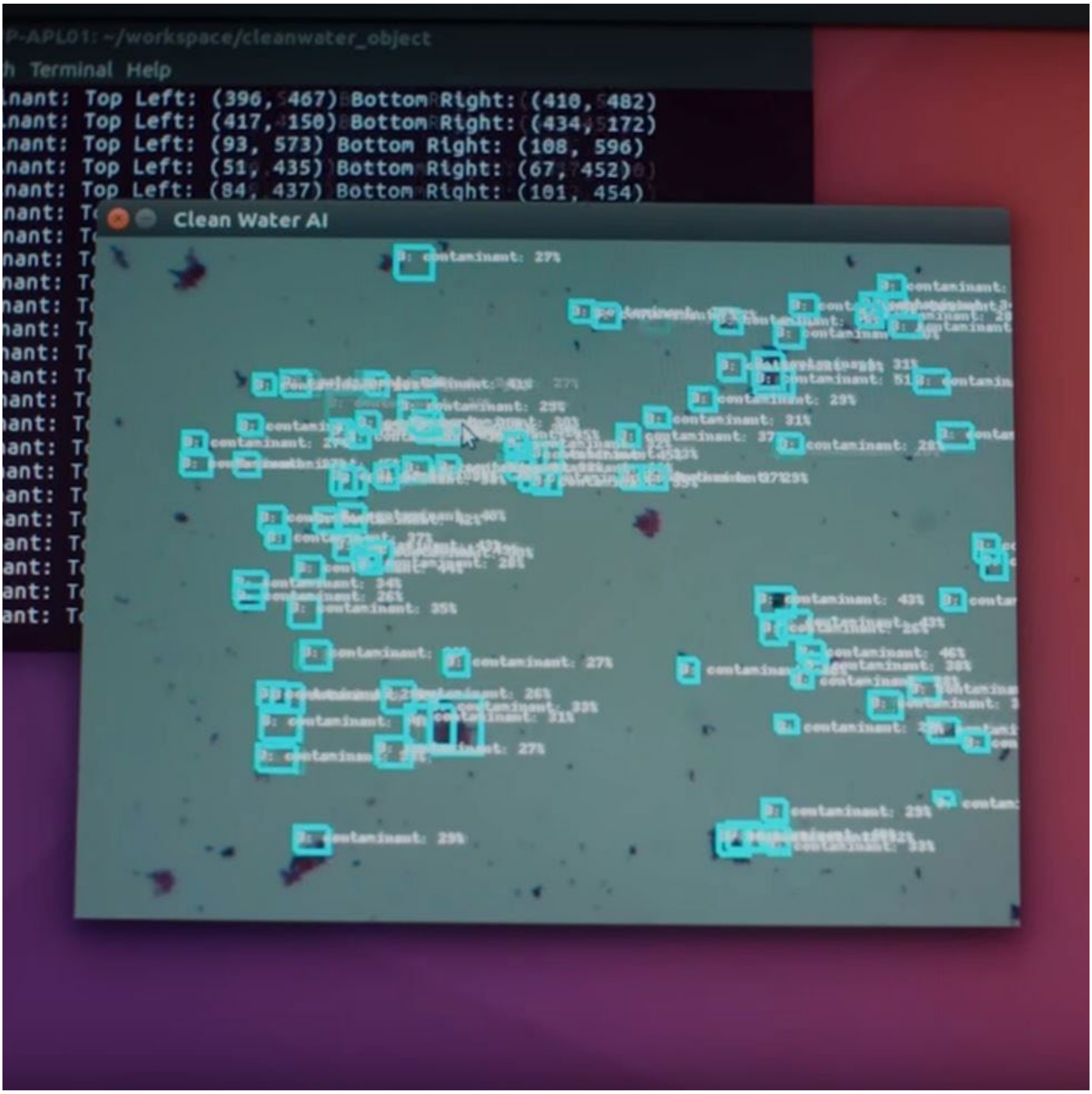


Image 7: Clean Water AI Open Source software, Source: Clean Water AI

model, *Clean Water AI* provides technical support for the software and runs the cloud services for the city. The company would also provide development services for optional dashboards and other features. This would enable cities to identify contaminated parts of their water supply systems more efficiently and by doing so improve water quality. This, in turn, would lead to fewer people becoming ill, which would benefit health systems.

The project entered and won the Microsoft AI Lab Challenge. This is validation from the market and clearly shows its potential. However, due to global challenges such as COVID-19 and trade wars between the U.S. and parts of the Middle and Far East, plans to roll out the project further in China, for example, are currently on hold.

Critical perspective

Stability – *Clean Water AI* is an operational, tested application for a narrow margin of customers. It is an extremely interesting application for cities and regions in developing countries as it would enable them to enhance their water monitoring capabilities when not using chlorine-based purification systems. The application and its IoT device could also be developed and trained further to detect other pollutants besides bacteria, making the devices and software even more useful. Many lives would be dependent on such a tool and so the AI must be built on a solid technology basis and be able to detect pollutants with a high level of accuracy.

Image 8: Let's Do It AI waste detection, Source: Let's Do It AI

HIGHLIGHTS

- Fully automated garbage detection based on existing image and video sources
- Improving quality of life in urban areas by helping authorities map garbage locations in up to near real time (e.g. from social media images of regions of a city)
- Monitoring garbage hotspots and the waste disposal behaviour of populations over time, enabling enhancement strategies to be developed for cities in future

Let’s Do It AI – Image-based waste detection

Background

The *Let’s Do It AI* project was established by the Let’s Do It Foundation, a public benefit organisation founded in Estonia in 2011 (https://letsdoitfoundation.org/). The project focuses on tackling environmental and social problems related to illegally dumped solid waste. It aims to support urban sustainability by automatically detecting waste and pinpointing its locations in online (and offline) images and videos. The project harnesses artificial intelligence (AI) for image pattern recognition and increases the efficiency of waste management. The idea was born out of a citizen participation mapping project in 2018, which crowdsourced pictures taken manually by the project’s participants to highlight the importance of ongoing waste problems in cities at a global level. The project organizers started to discuss and develop an AI approach back in 2018 in order to scale and automate the project and to make the data more accessible and affordable for citizens and administrations around the world. With the support of Microsoft as a project partner, *Let’s Do it AI* used existing, publicly available online images and video feeds together with photos from their own mobile app to train the AI to recognize waste in still and video images.

The software used in the *Let’s Do It AI* project is an open-source development and can be used free of charge in urban environments and anywhere else where pictures are taken. The resulting image data is available for analysis. The development of the AI software, from idea to solution, took one year and was funded with €60,000 provided by investors. This money was used for gathering data, creating a data labelling tool, carrying out the data labelling itself, developing the AI algorithm (model choice), testing the algorithm, adjusting the format of the training data and managing the project. In its current state, *Let’s do it AI* has not yet been implemented in any city, but it is ready to be deployed.

Let’s Do It AI’s project partners include:

- The Let’s Do It Foundation (partner and project lead)
- The University of California Riverside (UC Riverside)
- Microsoft
- CalTrans (a start-up specialized in AI)
- Volunteers from different backgrounds

The overall international team includes up to 20 experts and participants from Romania, the United States and Estonia.

The project supports the following Sustainable Development Goals (SDGs):

1. SDG 3 "Good Health and Well-being": By improving public health through safer and cleaner environmental conditions.
2. SDG 9 "Industry, Innovation and Infrastructure": By enhancing technology and access to information for improved services and infrastructure.
3. SDG 11 "Sustainable Cities and Communities": By ensuring access to basic, sustainable services.

Implementation

Technical framework

First, a requirements analysis was assessed. Then the corresponding AI was developed as a computer vision neural network capable of detecting waste patterns in images and videos using object detection and segmentation. An existing open-source model called YOLO was used in the initial development stages. This was later replaced by a region-based convolutional neural network (R-CNN) based on Python. Mask R-CNN is a convolutional neural network built on FPN and ResNet101 that uses residual blocks among convolutional layers. To train the model, the project used matterport's implementation of a Mask R-CNN framework, which was implemented in Python 3, Keras and TensorFlow. Computing power was provided by Microsoft Cloud solutions.

The development of the project can be summarized in the following five steps:

1. Collecting images – This was mostly done by the Let's Do It foundation and UC Riverside. The project uses any online and publicly available image files as input to train the algorithm, for example, images from Google Street View. It also makes use of the Let's Do It Foundation's own images collected in prior studies (such as the World Clean-up app).
2. Selecting images – The images used to train the model were chosen strategically, starting with a sample of images to analyse the results. These results were then used to select the images for the next iteration of training.
3. Object detection – The waste in every selected image was manually marked with the help of volunteers from the Let's Do It Foundation and UC Riverside. Over 1,000 images were annotated and used for AI training.
4. Training the machine learning model – Multiple iterations included updates and changes to the parameters of the Mask R-CNN model to improve the results, and new images were added to the training dataset.
5. Result validation and testing – After each training cycle, the best model was chosen and tested by getting it to predict trash on test images. These images were not included in the training dataset and were used to assess the accuracy of the model.

In more detail and as first step, initial available weights were selected in YOLO to train the model to detect waste (40 online images used for testing). The results were not satisfying, however, as the solution was not able to accurately detect waste. To increase detection precision, a Mask R-CNN Python implementation (introductory paper, GitHub) was then deployed, which included object detection and segmentation. Then, polygons were used instead marker boxes to detect waste using the VGG Image Annotator tool. After various iterations of refinement on the over 700 training images and later on Google Street View images, the algorithm was then ready to be deployed.

The algorithm has also been trained on different backdrops and different weather conditions, for example snow, to ensure it can deliver precise results all year round and in different regions of the world. All images contain geo and temporal information that is collected once the AI detects waste patterns in the image. Actions can then be taken by local stakeholders such as waste management companies and city authorities. In the case of CCTV footage, which is usually owned by a city or law enforcement agencies, an image can be pinpointed based on the location of the camera and does not have to be taken directly from the image.

Data management

Provided that the data used and collected by the project is open source or owned by the project leader and as long as no personal data is involved, there is no need to develop a data sharing agreement or framework. These documents were also not developed as a basis or reference framework for sharing data.

Risk management

Throughout the development and implementation phase, the team faced a number of challenges. Due to the innovative nature of the algorithm, its development was highly time consuming. Teaching the AI to identify waste itself and then training it to identify it in various environmental conditions proved to be particularly time consuming. Furthermore, the team had difficulty finding partners in the early stages and so the developers had to initially implement the project on their own system. As result of this, implementing the solution into city systems took longer than estimated. In parallel to the technical development, forming a sound legal foundation and ownership took time with involved parties when implemented in concrete contexts.

Governance & project management

Mitigation and governance approaches need to be developed by project stakeholders (local governments, waste management companies and citizens) for a specific use case.

Subsequent use

Transferability

Let's Do It AI can be transferred to other geographic contexts such as developing and emerging countries. Building on the project's successful deployment and testing, the Let's Do It Foundation is currently looking for funding and partners with whom they can verify their AI solution for the entire world. In addition to looking for potential partnerships with city governments, municipalities and waste management agencies, the foundation is holding talks with the Red Cross with the aim of identifying waste on a large scale more remote areas as well.

Ensuring public access to the source code is key to the pro-

Image 9: Let's Do It AI waste detection, Source: Let's Do It AI

ject's continued development. The long-term goal here is to make one billion people aware of the global waste problem. The Let's Do It Foundation is committed to this open source approach with regards to both data handling and ownership. In addition to relying on publicly available open data, the organization further proposes that it does not own or store any data itself. Instead, the data should be collected, managed and handled by cities and their existing infrastructures acting as a host (as is already the case with CCTV footage). In doing so, cities will not have to pay to use sources such as Google data. Instead, they will be able to use information from their own sources such as CCTV cameras located around a city. If the data stays on the client side, no additional regulations will be needed. Cities can then, for instance, visualise aggregated data when engaging in public discussion with the citizens.

Cost benefit & business model

Currently, the business model is in the design phase. The AI tool WADE is being integrated into municipal workflows to provide an extra layer of information about mismanaged waste found in images. When integrated into local municipality monitoring tools, the AI will provide an overview of mismanaged waste and littering and will be able to analyse if and how changes in waste management are affecting cleanliness of streets and public places. The system can be built up on the CCTV data flow. In other words, WADE can be integrated into existing systems to provide additional information when it identifies waste on streets or roadsides.

Critical perspective

Let's Do It AI is an operational application ready to be deployed in cities and regions that have access to up-to-date and regularly updated image data of their environment. The application can provide major benefits, for example by creating garbage hotspot maps in cities, thus eliminating the need for volunteers having to search for and monitor waste. The application can even create garbage maps over time, helping city administrations identify patterns in the behaviour of citizens. This information could then be used to create campaigns aimed at changing this behaviour.

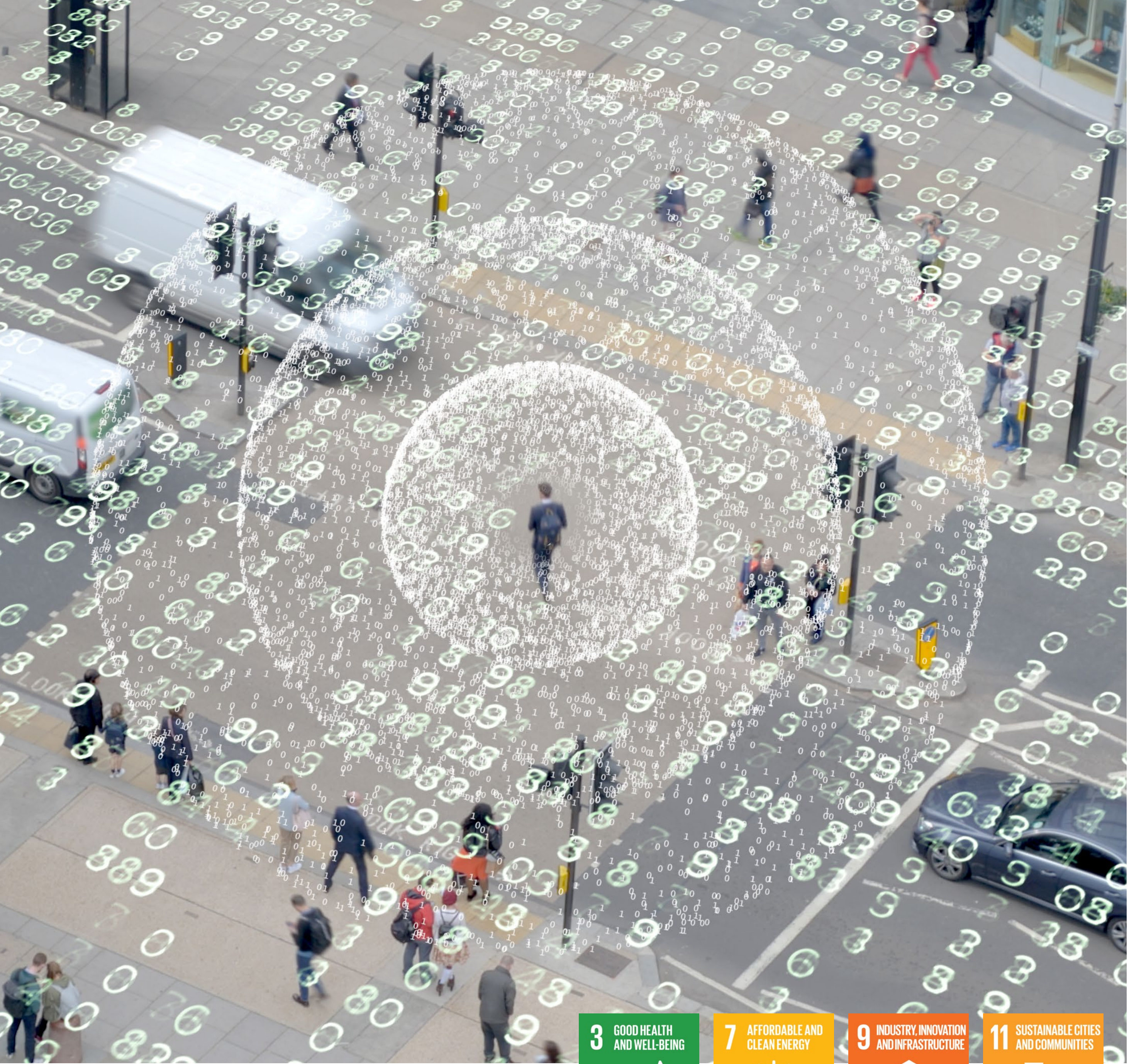


Image 10: Animation of traffic digitalisation, Source: Peter Howell, iStock

HIGHLIGHTS

- A system for integrating mobility, communications, energy, health and the environment.
- Improving urban health, traffic flows and infrastructure.
- Boosting the productivity and efficiency of local authorities at regional level through data science and the IoT.

Thames Valley Berkshire Live Labs – Integrated Urban Mobility in Berkshire, UK

Background

Berkshire is one of UK's most densely populated urban environments and suffers from heavy traffic congestion as vehicles travel into and out of London. Alongside traffic issues, this situation causes many other challenges from severe health problems for citizens to increased energy consumption in the area. The *Thames Valley Berkshire Live Labs* project aims to improve these conditions and increase urban quality of life by offering AI and data-driven solutions spanning the areas of mobility, communications, energy, health and the environment.

The project has received €5.5 million in funding from the UK government under the umbrella of the ADEPT (Association of Directors of Environment, Economy, Planning and Transport) SMART Places Live Labs programme.

The funding was distributed as follows: Data (€1,650,000), IoT hardware (€1,650,000), project management (€330,000), hardware modification (€825,000), innovation competition (€550,000), commons (€220,000) and contingency (€660,000).

The project is expected to be completed in November 2021 and includes following partners:

- O2/Telefonica (project lead): Key strategic role in collecting and cleansing mobile phone network and sensor data and providing this to relevant partners and stakeholders. Together with programme managers, O2/Telefonica is responsible for reporting the outcomes and benefits of the project.
- Siemens: Gathering data from 26 sensors over a period of six months in each area under investigation.
- WAYRA (tech-driven, open innovation hub): Recruiting start-ups.
- Smarter Grid Solutions (energy enterprise software company): Providing energy solutions.
- Reading Borough Council: Grant holder and client.
- Slough Borough Council: Grant holder and client.
- University of Reading: Disseminating outcomes in the form of research publications.
- Multiple start-ups related to data science and the Internet of Things (IoT).

Within this framework, the *Thames Valley Berkshire Live Labs* project focuses on five interrelated sub-projects, each encouraging community involvement with opportunities to get involved through live trials as they develop:

- *Road Surface Quality*: This sub-project predicts the appearance of potholes on roads. In conjunction with the Traffic Flow sub-project (below), this will create an intelligent traffic system capable of reducing congestion.
- *Traffic Flow*: This sub-project aims to improve the way traffic flow signals are operated in order to reduce congestion. This will result in a model capable of predicting traffic patterns up to 20 minutes in advance. The model will be controlled via a

web interface, enabling authorities to take informed action.
- *Energy*: This sub-project explores the need for charging capacity for electric vehicles with increasing quantity on renewable energy generation. Outcome informs energy managers in suggesting vehicle charging timeslots based on efficiency.
- *Air Quality*: This sub-project explores how mobility patterns impact air quality and what affect this has on public health. It aims to improve the accuracy of statistical models used to predict air quality.
- *Public Health*: This sub-project uses big data to explore the relationship between personal mobility and public health. As mobility has a significant impact on personal well-being, this sub-project aims to develop a model based on geographic parameters and observed behavioural data. The model will then be used to identify areas at high risk of obesity (due to a lack of mobility), loneliness (due to a lack of social interaction) and alcoholism (as result of loneliness) within the population.

All five sub-projects are highly interrelated and dependent on each other. A greater road surface quality and smooth traffic flow positively affects both energy consumption and air quality, which in turn impacts public health. However, due to limited council funding, road maintenance teams face challenges in detecting and fixing potholes efficiently on Berkshire's heavily used roads, which include the A4 and A322, two of the most important routes into and out of London. This leads to accidents and damage to vehicles. The increase in traffic noise, poorer air quality and a higher energy demands also causes health, well-being and productivity issues for residents.

To tackle these challenges, the web-based platform informs local authorities about the most heavily used routes with the poorest road surface qualities, enabling them to take informed, preventive actions. The project aims to reduce vehicle damage and improve road safety, while at the same time making roads more efficient. To this end, it combines various datasets to create a real-time view of network activities, providing previously unavailable information about the types of trips taken, starting points, destinations and how incidents affect the network. In addition to this, the platform provides real-time feedback on demand for bus stops and seat occupancy in public transport. It also dynamically calculates the charging capacity required for electric vehicles (EV), factoring in reusable energy generation to increase energy efficiency.

The project also aims to help people suffering from problems with their respiratory systems. An innovative air quality measurement system is being developed for the region that will be able to calculate and analyse exposure to NOx, particulate matter (PM2.5, PM10) and CO emissions. The system will then share this information with citizens and enable them to take appropriate action. This also includes long-term public health challenges related to the population's mobility and their access to jobs, retail and leisure facilities, green spaces, social interaction and well-being (tackling the risk of obesity, alcoholism and loneliness). The aim here is to understand how actual mobility and potential mobility patterns are related to public health problems such as the ones mentioned above.

The project supports the following Sustainable Development Goals (SDGs):

1. SDG 3 "Good Health and Well-being": By reducing illness and deaths related to hazardous chemicals, pollution and road injuries.
2. SDG 7 "Affordable and Clean Energy": By promoting the use of renewable energy and increasing the global percentage of renewable energy.
3. SDG 9 "Industry, Innovation and Infrastructure": By developing sustainable, resilient and inclusive infrastructures.
4. SDG 11 "Sustainable Cities and Communities": By providing access to safe and sustainable transport systems and reducing the environmental impact of cities.

Implementation

Like all Thames Valley Berkshire Live Lab sub-projects, the mobility-related projects have been implemented over a period of three years in the Thames Valley (located west of London in southeast England (UK)). The projects focus on main road network arteries such as the A4 and A322.

To comply with procurement regulations and stay below certain thresholds, O2 structured the project in line with the project areas outlined above. This structure of sub-projects within the main overarching project reflects the highly complex and interrelated challenges faced by the local authorities. As a result, and unlike most current AI projects, which tend to focus on just one rather small topic, this project takes an integrated approach and focuses on all themes.

Technical framework

A requirements analysis was created both for the AI system and the expertise needed to develop the AI application. Experts were recruited through an innovation competition for start-ups initiated by O2/Telefonica (Wayra). In terms of technology, AI is being used to:

- predict the locations of potholes and their grades of severity,
- locate potholes which cause the highest instances of damage to vehicles or personal injuries,
- locate potholes which create the most noise and negatively affect people's well-being,
- detect and define rules for a traffic prediction system to initiate changes based on different levels of congestion,
- develop an air quality model related to people's activity,
- balance energy used for charging EVs and the generation of reusable energy and
- measure the relationship between personal mobility and various public health aspects.

Data management

Besides O2's mobile network data and publicly available open-source data, the project uses traffic signal data (from Berkshire's local authorities and Siemens), vehicle GeoTab telematics data (GPS fleet tracking), data collected by traffic system loop counters, Bluetooth journey time monitors and automatic number plate recognition (ANPR) cameras. Data from air quality sensors and open data from various public sectors such as retail and health are also being integrated. A dedicated cloud service (Amazon Web Services (AWS)) is used to store the data used, ensuring access to decent computing power.

Risk management

The project is based on an open-source approach. To avoid privacy issues and ensure that the solution is scalable and will be legally compliant for future deployment in other areas and countries worldwide, no personally identifiable information (PII) is collected or used and all census and location-based data is anonymised and aggregated. Furthermore, the open-source nature of the implementation means that no agreement or framework on data sharing is needed. A mitigation and governance approach has been developed using a privacy impact assessment. Possible risks were tackled by establishing a risk register and dedicated team responsibilities for data processing, management, sharing and end use.

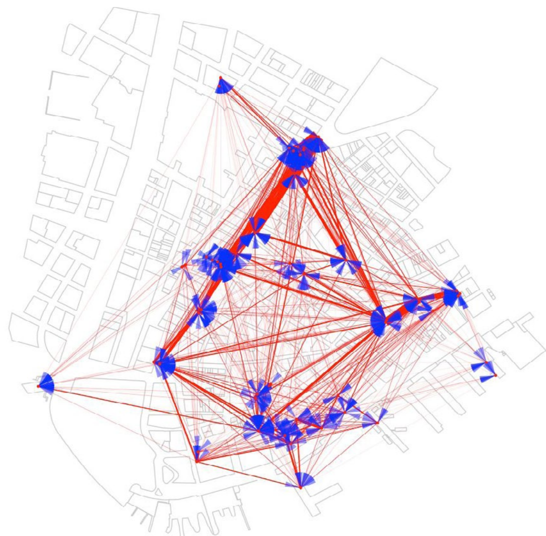


Image 11: Example of modeling movement in urban environments, Source: Traunmueller M., et al, 2018

Governance & project management

The project includes multiple partners, private companies, local councils and research institutes. Its progress is tracked by a monthly steering group meeting. A delivery team adds details and is responsible for procurement processes. The budget is controlled by Reading Borough Council (RBC) which is a grant holder and the client. RBC is responsible for project governance and scrutiny, ensuring that all expenditure is spent in accordance with grant conditions and local authority requirements.

Subsequent use

Transferability

The replicability and scalability of the above trials are key to the success of the project. The results of the Berkshire deployment are highly promising and can be replicated in other regions of the world, independent of their cultural background as long as baseline requirements such as the availability of mobile phone data and maintenance of IoT devices are met. In terms of the project's technical development, the team is focusing on adapting the project for use in less developed countries. This includes looking at the challenges of data accessibility, availability and accuracy as well as sharing data on a city-wide scale. The rising numbers of smartphone users in less developed countries will help the project be a success in these parts of the world too. It will then be possible to adapt and tailor the project's models to these countries based on the specific needs and challenges of the stakeholders there, the availability of data and the involvement of local authorities.

Cost benefit & business model

The project works with strong partners from the private sector and is therefore already sustainable. It has also received excellent press and interest from cities all over the world, resulting in it already having a social impact. Traffic and congestion levels are increasing across the world, posing challenges to public health and urban sustainability. The need for this innovation is therefore obvious. In addition to the mobility services provided by the project, the availability of the data will also open doors for developers and other service providers, enabling them to build new tools on top of the existing ones.

The project's business model is currently under development and will be a combination of software, data and service provisioning based on a monthly or annual subscription fee for interested stakeholders such as local governments, municipalities and planners.

Critical perspective

- Authorities – In its current state, the project is funded by the government and dependent on strong stakeholders and ownership within the local government sector. Local authority engagement, awareness of existing problems and the will to introduce changes through innovation in order to solve these problems are key to any further deployments.
- Defining problems – Before choosing a specific technology, the problems and challenges of the region in question need to be identified. A diagnostics exercise aimed at identifying a city's structural problems (economic, social, infrastructure issues, for example) can help formulate true, worthwhile objectives. Answering the question '*Why does a certain problem occur?*' is much more important than considering '*What technologies should be developed in a certain place?*'.
- Data privacy – Using mobile phone data as basis for all of the sub-projects presented here poses challenges in terms of data privacy and transparency. Mobile phones are always carried close to people's bodies, in their pockets for example. As such, they deliver highly confidential data about an individual, in particular their location at any given time. Using this type of sensitive data for any kind of technological innovation – from predicting travel patterns to the public health issues outlined here – requires in-depth quality control to prevent any kind of misuse.

Reflection & Recommendations

Artificial intelligence has been at the forefront of technological advancements in recent years due to ongoing developments in algorithms, access to an increasing amount of data from various sources and computing power. Applications of AI can be powerful tools to help achieve the goals and principles of the 2030 Agenda in urban contexts. This report analyses six AI-powered use cases that focus on urban planning, improving public financing, building, water/wastewater, waste management and mobility. All of the identified use cases are promising proofs of concept, some are already operating in real urban environments. This presents an opportunity to organizations of the German Development Cooperation to adapt these use cases to the needs of their projects and stakeholders and scale them up for achieving impacts related to the SDGs.

When doing so, certain aspects should be considered following the insights of this report.

Problem- and human-centred approach

As this report shows, AI technology can be hugely beneficial to international collaboration and development work. However, it is important to stress that as with most other technologies, AI cannot be seen as the only solution for tackling the challenges that countries, regions and cities face. AI technology is a vehicle that supports a solution. But it is not the solution itself.

First of all, the challenge needs to be identified. Then, the technological solution that best solves this problem has to be chosen. Finally, the technology has to be embedded in a context that supports all aspects of the challenge in question. In the case of waste, for example, being able to identify trash in a neighbourhood using AI image recognition is a huge benefit. However, if there is no solution in place for collecting this waste, identifying it is pointless. To solve this waste challenge, the relevant authorities must develop means of identifying *and* collecting the waste if they want to improve the current situation.

In the example of *Ho Chi Minh City*, using AI to identify land use is a massive technological step forward. However, the results also need to be verified regularly to ensure the output is of a high quality and the datasets are regularly updated. At the same time, project participants have to establish ways of accessing this data and participating in its development and implementation in order to fast track local innovation and ensure that all citizens benefit and no one is left behind.

In the case of the waste recognition application, cultural changes regarding littering in general might have to be introduced initially and awareness of the problem developed. Only then would it make sense to implement the AI solution. A functional waste collection system including public and private bins as well as regular waste collection and proper landfills or recycling plants is need as well to ensure proper pick-up and disposal after indication are made.

However, these systems should not be deployed in a technology-driven way. Rather, the way in which they will be used by citizens and local administrative bodies should be the key consideration. Hence, potential applications for AI should be based on the needs articulated by citizens, and citizens should be involved in identifying where AI systems can be used. The systems should be developed using a user-centric approach and carefully explained to users.

The central focus for the development of AI must be the needs of city residents and the requirements for an integrated, sustainable approach to urban development. AI systems should be used as levers to make processes more efficient, effective, transparent and inclusive, which will in turn allow them to act as levers for the implementation of 2030 Agenda in cities.

Considerations for future project structures

Based on these findings, we can issue the following recommendations for successful implementation and maximum impact moving forward:

Integrated approach

- **Intersectoral integration:** In projects that focused on interrelated topics, we found that collaboration between sectors helped maximize these projects' impact. This is clearly shown in the mobility use case described in this report. In this example, Reading Council and Telefonica/O2 were two of the lead partners for the *Thames Valley Berkshire Live Labs* project. Five interrelated sub-projects are discussed in this lab environment: Road surface quality, traffic flow, energy, air quality and public health. All of these areas are very closely related.
- **Multi-stakeholder partnership:** Involving stakeholders from various sectors brings in a wide range of skills, expertise and different perspectives. Involving parties such as the public sector, private economy and academia leads to strong consortia capable of tackling real-world problems and ensures eco-

nomic sustainability and scientific soundness.
- **Setting up new network structures:** Platforms that bring together different stakeholders such as tech companies, SMEs and government bodies provide the perfect backdrop for sharing information and establishing the connections needed for developing new ideas and projects. The start-up accelerator WAYRA, which was founded in partnership with Telefonica (mobility use case), is a prime example of this. In this example, WAYRA was used as platform for the project to find partners with the expertise required for the solution, including AI experts from various start-up ventures.

Governance and project management

Based on the examples described in this report, there are clear differences in the structures and initial setup of the projects. The projects can be differentiated as follows:

- **Top-down funded projects:** These kinds of projects receive government funding or are financed through research calls for a fixed number of years. Companies and interested parties can propose a project and request funding individually or as consortium. The winner receives funding for developing and executing the project. (Examples include the use cases for urban planning, financing, building and mobility.)
- **Bottom-up initiated projects:** These kinds of projects are developed, financed and executed by private businesses including start-up initiatives. Businesses and start-ups develop an idea for a prototype which can be tested and further developed and improved at a later stage. The project's journey is organic, and investments are generated by attracting partners and investors. As a result, this approach is much more demand and business driven. (Examples include the use cases for water/wastewater and waste management described above.)

These fundamental structural differences affect potential partner constellations and also influence how the project team is defined. Our findings for this report suggest that the main partners should be assigned specific roles, which results in the following management structure:

- **Public body:** This includes city governments, municipalities and councils. These organizations head up funded projects. They define the real-world problems to be tackled by the project, for instance, managing land use changes in Ho Chi Minh City (see the urban planning use case.)
- **Funding body:** This can be institutions such as the international or national development Banks or agencies and other donors. These organizations initiate projects by tendering or publishing research calls. They also work with the project lead to ensure that the project is progressing and it is a success.
- **Private technology companies:** Companies such as Microsoft and Telefonica/O2 can be key partners in projects, especially when a lot of computing power is needed. As showcased the can be responsible for various technological development tasks as well as the final implementation. Reporting to project leads is crucial for transparency, alignment of objectives and for ensuring digital development principles are respected.
- **Start-ups:** In the role of project initiators, start-ups can act as the technical and business leads. These highly specialized key technology developers work collaboratively with project partners or could even drive the technical solution for the identified challenge. When part of top-down funded projects, they might act as junior partners or subcontractors. They are highly specialized in specific technologies (in the context of this report most often related to the development of an AI algorithm).
- **Universities:** Expertise on machine learning techniques, algorithm development and training often reside with researchers of universities. As the case of Peru showcases, they ensure that the science behind projects is sound and publish scientific results.
- **Civil society organizations:** Depending on the challenges they are trying to tackle, AI projects may have to engage with local communities - directly or through their representatives. Civil society organizations provide deep context knowledge and may be important partners to engage with local communities as they speak the language(s) of the target group to ensure the project can reach highly diverse audiences. This is especially important if a project is dependent on crowdsourcing. Workshops and outreach events help raise awareness and improve understanding within communities and provide the opportunity for gaining direct feedback from potential users.

Management of technical challenges

- **Infrastructure (sensors, compute, internet, electricity):** Well developed basic infrastructure in terms of stable electricity and internet supply is a precondition for implementing AI systems as well as the availability of data (e.g. through sensors, public/census data or other sources). If this is not given it needs to be built up beforehand. Costs and benefits should be weighed up in advance. Another critical aspect to be considered is data storage. Deciding on cloud or local servers (such as in the case of inBetween) has implications for data security and availability as well as costs. While local servers are more secure, they are also more cost-intensive in the acquisition and require high capacities in maintenance and logistics. The good news is that costs for sensors lower, high speed internet is being rapidly expanding in many countries and cloud solutions enable progress through global cooperation and exchange.
- **Capacity building / training:** If a real-world implementation is going to need staff to manage and maintain the AI-driven solution in the long term, we highly recommend involving and working closely with local partners. However, in less developed countries in particular, it is important to ensure that the people involved have the knowledge and skills to support the project. We recommend carrying out continuous capacity-building and training measures throughout the course of a project, right from an early stage, to smooth out any differences in skills. This should be led by the local partners.
- **Data management:** Some critical questions need to be answered before setting up an AI project. Adequate technical

and organizational measures must be implemented to ensure that data availability is appropriate from a privacy perspective and access is secured. Furthermore, ensuring the quality of data is crucial to avoid adverse affects produced by "biased" machines, such as discrimination against people or places underrepresented in the underlying data sets. Especially securing personal data is essential[5]. For most applications, the collection and processing of data are continuous, rather than one-off, processes, and therefore require a suitable data management system. In addition, many applications of AI systems require the integration of data from a variety of sources. This is also the case for the kind of geographical (GIS) data required for most city-based systems.

In areas where large quantities of data are not yet available, the costs associated with collecting and managing the data must be weighed against the potential increase in efficiency that AI-powered services could bring. Hence, the creation of open data pools in areas relevant to sustainable urban development could represent an important focus, as this would reduce the barriers to entry for local AI developers.

Risk management

- **Independence:** Independent technical development is vital for creating artificial intelligence algorithms that will be used to make decisions that impact public life. If it is not developed independently, AI can be trained to provide skewed outcomes, leaning towards the subjective interests of related parties. To ensure an AI solution functions properly and is ethically sound, in-depth quality control measures must be hardwired into its development in the early stages to prevent any bias in its performance or outcomes. Commonly developed safeguards are recommended to ensure integrated and inclusive outcomes.
- **Ensuring inclusiveness:** AI is a powerful technology that can also go wrong. Flaws in the data sets and in the weighting of variables in algorithms may lead to discriminatory outcomes or misuse of the AI-powered solution. Technology-focused AI developers may not be aware of possible adverse outcomes due to a lack of deep context knowledge on the actual problem to be solved. Parts of local communities may not be able or willing to participate in AI projects. Thus, in order to ensure inclusiveness and instil trust in the new technology, transparent, clear and continuous communication with the concerned stakeholders is a key factor to the success of any AI project. Furthermore, safeguards will be needed and explained in order to meet the requirement for non-discriminatory, human-centric AI (e.g. to ensure privacy is respected, and to provide fairness, transparency and accountability). With a series of scandals triggering increasing concern about the privacy and ethical implications of AI systems, human-centric AI is becoming an ever more important issue. The way this issue is addressed will determine whether AI technologies are seen as legitimate in individual societies over the long term.

5 Computer-assisted anonymisation processes have now been developed for this purpose.

- **Data privacy:** A particularly important aspect that ensures inclusiveness and in turn acceptance levels is if everyone involved knows how and where the data will be collected and what it will be used for. Hence, robust quality control measures that ensure compliance with the applicable data privacy rules and regulations (e.g. GDPR requirements, other local law or adopted privacy standards) are paramount. Adequate data privacy measures mitigate risks for people affected by potential misuse of personal data and legal, reputational and operational risks for all project parties involved. Thus, every project working with personal data should incorporate data privacy considerations from the beginning.

Conditions for transferability

- **Infrastructure:** Like any technology, AI has to be implemented where it makes sense in developing regions. A highly advanced IoT application, for example, might not be suitable for a city or region if the current infrastructure does not enable IoT devices to be used in a meaningful way. In this case, the first step would be to develop the requisite infrastructure and integrate IoT devices later down the line.
- **Data availability:** For machines to learn adequately and draw accurate conclusions, predictions and/or recommendations data must be available in sufficient quantity and quality. For algorithms to be able to draw accurate inferences, developers must have access to a large quantity of structured, labelled data in a machine-readable format. Particularly for societal applications, the algorithms also require highly representative (training) data, for example in terms of the social groups and city districts it covers. This reduces the risk of distorted or downright discriminatory conclusions being drawn by the system. Therefore, ensuring a sound amount of qualitative data is key for a successfully implementation of an AI system. AI systems not relying on personal data might be better suitable to transfer due lower sensitivity and context reliance.
- **Open standards:** One approach to enable transferability of an AI project is using open standards, when developing algorithms, platforms or software. Furthermore, open approaches can help increasing cooperation and avoiding duplication.
- **Acceptance and commitment:** Creating cooperative ownership among various users and acceptance in the target group (e.g. citizens) are necessary for a successful implementation. Acceptance can be created through open standards, transparency a good communication and mostly through participation. Ownership and commitment by clear tasks and responsibilities as well as proper steering and exchange on par.

Cost-benefit and business model

- Developing AI is cost-intensive. Computing power costs money, as does the work done by AI specialists. Effective implementation of data strategies requires time and coordination. There is a danger of societal and reputation damage if these facts are not taken adequately into account. Therefore, it is important to think very carefully about the types of AI systems to be developed and why. The answers to these ques-

Image 12: Animation of Argumented reality and Smart City technology. Source: Sasin Paraksa, iStock

tions must be clearly defined before developing and training algorithms begins. Since an individual AI system can only solve a very narrowly defined problem, it will be important to determine which AI-assisted processes and products should be prioritised. Cost-benefit may vary according to local infrastructures and capacities.

- **Focus on economic sustainability:** AI is still a very novel approach that is used to help find solutions for specific challenges, particularly in highly complex urban contexts. As such, there is very little in the way of past experiences or business models that provide knowledge or insights. However, ensuring a project's economic sustainability is key to its long-term success. Initiated projects (such as start-up initiatives) face this challenge throughout their organically evolving development and steadily review and improve their business models to ensure they succeed on the market. Funded projects, however, need to ensure their economic sustainability after the funding has ended. As such, an in-depth assessment and solid business model have to be created for the solution in the early stages – even during the tendering process – to ensure it is economically sustainable in the long-run and after the project has ended. In this report we outlined six highly successful and promising solutions. However, our desk research during early stages of the report revealed a high number of less successful projects, which emphasizes just how important these challenges are.

Glossary

	Term	Description
AI	Artificial intelligence	Artificial intelligence (AI), the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings.
ANPR	Automatic Number Plate Recognition	Automatic number-plate recognition (ANPR) is a technology that uses optical character recognition on images to read vehicle registration plates to create vehicle location data
API	Application Programming Interface	An application programming interface (API) is a computing interface that defines interactions between multiple software intermediaries. It defines the kinds of calls or requests that can be made, how to make them, the data formats that should be used, the conventions to follow.
AWS	Amazon Web Services	Amazon Web Services (AWS) is a subsidiary of Amazon providing on-demand cloud computing platforms and APIs to individuals, companies, and governments, on a metered pay-as-you-go basis.
BIRCH	Birch clustering algo-rithm	BIRCH (balanced iterative reducing and clustering using hierarchies) is an unsu-pervised data mining algorithm used to perform hierarchical clustering over par-ticularly large data-sets
CCTV	Closed Circuit Television	CCTV (closed-circuit television) is a TV system in which signals are not publicly distributed but are monitored, primarily for surveillance and security purposes
	Correlation analysis	Correlation analysis is a statistical method used to evaluate the strength of relation-ship between two quantitative variables. A high correlation means that two or more variables have a strong relationship with each other, while a weak correlation means that the variables are hardly related.
GDPR	General Data Protection Regulation	The General Data Protection Regulation 2016/679 is a regulation in EU law on data protection and privacy in the European Union and the European Economic Area. It also addresses the transfer of personal data outside the EU and EEA areas
	Genism	Gensim is an open-source library for unsupervised topic modelling and natural language processing, using modern statistical machine learning.
IoT	Internet of Things	The Internet of things describes the network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the Internet.
	K-Means clustering	k-means clustering is a method of vector quantization, originally from signal pro-cessing, that aims to partition n observations into k clusters in which each observa-tion belongs to the cluster with the nearest mean, serving as a prototype of the clus-ter.

	Term	Description
ML	Machine Learning	Machine learning is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. Machine learning focuses on the development of computer programs that can access data and use it learn for themselves.
NILM	Non-Intrusive Load Monitoring	Nonintrusive load monitoring, or nonintrusive appliance load monitoring, is a process for analysing changes in the voltage and current going into a house and deducing what appliances are used in the house as well as their individual energy consumption
NLP	Natural Language Processing	Natural language processing (NLP) is a subfield of linguistics, computer science, and artificial intelligence concerned with the interactions between computers and human language, in particular how to program computers to process and analyse large amounts of natural language data.
PII	personal identifiable information	Personally, identifiable information, or PII, is any data that could potentially be used to identify a particular person. Examples include a full name, Social Security number, driver's license number, bank account number, passport number, and email address.
	Python	Programming Language
RNN	Recurrent Neural Network	A recurrent neural network is a class of artificial neural networks where connections between nodes form a directed graph along a temporal sequence. This allows it to exhibit temporal dynamic behaviour.
RBC	Reading Borough Council	Council in Reading, UK, west of London
	TensorFlow	TensorFlow is Google's free and open-source software library for machine learning. It can be used across a range of tasks but has a particular focus on training and inference of deep neural networks
VR	Virtual Reality	Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. Applications of virtual reality can include entertainment (i.e. video games) and educational purposes (i.e. medical or military training). The immersive VR changes your view when you move your head.

Appendix A: List of Interview Partners

Topic / Chapter	Company	Name / Position
Urban Planning	• Ho Chi Minh City Municipality • World Bank	• Kien C.Vu / Deputy Head of General Planning Division • Kai Kaiser / Senior Economist
Mobility	• O2 / Telefonica, UK	• Alastair McMahon / Analytics Director
Waste Management	• Let's Do It Foundation	• Kristiina Kerge @KergeKerge / Tech Innovation Lead
Financing	• Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH	• Victor Manuel Morales Palacios / Adviser
Water / Wastewater	• Clean Water AI	• Peter Ma / CEO
Building	• AIT Austrian Institute of Technology	• Milos Sipetic / Scientist

Appendix B: Interview questions

1. Background questions about the interviewee

What is the name of your company?	
What services do you provide?	
What is the size of your company?	
What is your role within the company?	

2. General:

What is the Use Case? To what extent does the AI application solve the problem or what added value does the AI application offer in the context of the use case?	
Why was the AI system / solution developed? Where did the impulse come from? (e.g. data availability, user demand, supply from companies, implementation of an AI strategy)	
Who was involved in the development and implementation?	
Who was in the lead?	
Team structure?	
How were users involved?	

3. Subsequent use

Who owns the data collected for the AI? Who has access or usage rights? Are insights or aggregated data shared with the public?	
Who administers the AI application and how is it ensured that it is used in the regular processes of the city administration?	
How is the technical maintenance of the system ensured?	
To what extent have users* involved been trained and educated to operate the system independently?	
How does the interaction between user* and AI application take place; what is required beyond technological understanding / new challenge in the application/operation/understanding / task? Which role profiles result from this, especially for the city administration?	

4. Assessment

And what are the key success factors? Local expertise, partnerships, technical AI expertise, etc.	
How is the sustainable business model designed?	
What is the relationship between costs and benefits from the perspective of the city administration?	
Can the application example be transferred to other contexts, especially to developing and/or emerging countries? What are the most important prerequisites and conditions for this?	

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