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Effective use cases on employing artificial intelligence for achieving sustainable development goals and their applications in smart sustainable cities

ITU-T FG-AI4EE Deliverable

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Summary

The motivation for smart sustainable cities (SSCs) is derived mainly from sustainable development goal (SDG) number 11. This report however employs a more comprehensive analysis through which it treats smart sustainable cities as a catalyst for implementing all 17 sustainable development goals (SDGs). In particular, we examine the role of artificial intelligence (AI) as an effective vehicle for delivering these SDGs. Six case studies have been briefly analysed, highlighting their economic, social, and environmental impact on sustainability. The analysis of these six cases is built on the expertise of the International Telecommunication Union (ITU), experience of the United for Smart Cities organization, recommendations of international standards organizations (ISOs), and practices of the AI4Good community. Analysed cases span over diverse domains, including disaster management, food security, transportation, biodiversity, energy management, and knowledge management. The report also outlines sustainability-centric key performance indicators (KPIs), best practices, and policy recommendations to inform efforts that focus on employing AI for achieving SDGs in the context of smart communities.

Keywords

Artificial intelligence, biodiversity, disaster management, food security, knowledge management, smart grids, smart sustainable cities, smart transportation, sustainable development goals.

Note

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

Change Log

This document contains Version 1.0 of the ITU-T Technical Report on "*Effective use cases on artificial intelligence for smart sustainable cities*" approved at FG-AI4EE sixth meeting held in Ålesund, Norway, 1-2 December 2022.

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1 Scope and approach

Smart sustainable cities (SSCs) are the de-facto model for the future cities built on smartness and sustainability. The term 'smartness' refers to that quality of contributing to sustainable development and resilience through soundly based decision-making and the adoption of a long- and short-term perspective. One major aspect of this smartness is the growing reliance on artificial intelligence (AI) to conduct social, economic, public, and personal activities. The term 'sustainability' means that activities in such smart sustainable cities respect the sustainable development goals (SDGs) set by members of the United Nations in 2015.

The purpose of this Technical Report is to present effective use cases of AI applications that contribute to the ambitions of SSCs and the SDGs as well. We attempt to choose cases, or technologies, that effectively serve multiple SDGs. The term 'effectiveness' here means to what extent discussed AI applications contribute to SDGs. While presenting selected use cases, we provide a brief overview of the technology and its alternatives if any, and we relate their social, economic, and environmental impact to SDGs. Sustainability is usually ignored in the traditions of governance of SSCs. As shown in Table 1, governance and policies only consider urban planning, citizen engagement, and city operations and finance, without any reference to sustainability [b-WEF]. In this report we provide sustainability related key performance indicators (KPIs) and policy recommendations in order to improve the sustainability credentials SSC governance. Hopefully, managers will use these KPIs to assess to what extent adopted technologies contribute to SDGs. In addition, best practices, regulatory issues, socio-economic factors, and environmental impacts are discussed to inform stakeholders on how to effectively build on these real-world use cases. We believe that an effective contribution to sustainability needs to deploy domain-specific performance indicators, recommendations and also best practices. This is because the approach of SSCs in urban development spans over a wide range of contexts and practical fields such as manufacturing, commerce, transportation, healthcare, waste management, energy management, and pollution.

2 References

[FG-AI4EE] FG-AI4EED.WG1-04, *List of Key Performance Indicators (KPIs) for small and medium enterprises to assess the achievement of sustainable development goals*. https://handle.itu.int/11.1002/pub/81a36bd6-en

[ISO] ISO/FDIS 37106:2021(E), *Sustainable cities and communities – Guidance on establishing smart city operating models for sustainable communities*.

[UN] The United Nations, *Do you know all 17 SDGs*. accessed 06/02/2023 https://sdgs.un.org/goals

[IBM] IBM *Maximo Equipment Maintenance Assistant V1.1.1 User Guide*.

3 Definitions

3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

3.1.1 smart sustainable city [b-ITU-T Y.4900]: A smart sustainable city is an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban operations and services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects.

NOTE – City competitiveness refers to policies, institutions, strategies and processes that determine the city's sustainable productivity.

3.1.2 eco-efficiency [b-Yadong]: The term eco-efficiency refers to models, techniques, and practices that switch an economy or organization from unsustainable development to a sustainable one.

3.1.3 smart grid [b-EC]: An electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it such as generators, consumers and those that do both to ensure a low-loss, economically viable, sustainable power system with high quality and security of supply.

NOTE – Definition adapted from the EU commission Task Force for Smart Grids.

3.1.4 smartness [b-ISO 37101]: Quality of contributing to sustainable development and resilience, through soundly based decision-making and the adoption of a long- and short-term perspective.

NOTE – A major aspect of this smartness is the growing reliance on artificial intelligence (AI) to conduct social, economic, public, and personal activities.

3.2 Terms defined in this Technical Report

This Technical Report defines the following terms:

3.2.1 vehicle platooning: In intelligent transportation, vehicle platooning is a method of vehicle-to-vehicle collaboration where a group of vehicles drive together in-line in a group of 3 to 20 vehicles or trucks. Vehicles use artificial intelligence to collect, analyse, and share data for safety and vehicles can join and leave the platoon.

3.2.2 vehicle to vehicle collaboration (V2V): In intelligent transportation systems (ITS) and smart roads, Vehicle to vehicle collaboration (V2V) are vehicles equipped with sensors, cameras, algorithms, and other smart devices and exchange road conditions, speed, position, directions, hazards, and threats with other vehicles.

3.2.3 vehicle-to-infrastructure (V2I): A communication model in which vehicles use smart devices and algorithms to share and access information from traffic and road infrastructure. Used devices and infrastructure include traffic lights, radio frequency identification (RFID) readers, cameras, sensors, lane markers, streetlights, signage, and parking meters. Exchanged information include speed, position, road conditions, heading angle, and threats.

3.2.4 sustainability: Strategies producing more products and services with less resources, waste, and pollution.

3.2.5 intelligent transportation systems (ITS): Systems, devices, and models that increase productivity of transportation while reducing its social, economic, and environmental costs of transportation.

3.2.6 sustainability-centric: When a business process and its artificial intelligence (AI) application are designed and implemented to achieve certain sustainable development goals (SDGs), rather than the needs of citizens or ambitions of local development.

4 Abbreviations and acronyms

This Technical Report uses the following abbreviations and acronyms:

ADA Advanced Driving Assistant

AI Artificial Intelligence

ANN	Artificial Neural Network
API	Application Programming Interface
CIM	Common Information Model
CIRCLES	Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing
GA	Genetic Algorithm
GPS	Global Positioning System
FTF	First-Time Fixes
ICT	Information and Communication Technology
IoT	Internet of Things
ISO	International Standardization Organization
ITS	Intelligent Transportation Systems
KPI	Key Performance Indicator
ML	Machine Learning
MTTR	Mean Time To Repair
NLP	Natural Language Processing
PRGBNNs	Polak–Ribiére gradient back propagation networks
RFID	Radio Frequency Identification
RL	Reinforcement Learning
SDG	Sustainable Development Goal
SG	Smart Grid
SKM	Smart Knowledge Management
SMIP	Stochastic Mixed-Integer Programming
SSC	Smart Sustainable City
UNGA	United Nations General Assembly
UNOSAT	United Nations Satellite Centre
U4SSC	United for Smart Sustainable Cities
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle

5 Model of smart sustainable cities

Ever since the industrial revolution, workers have been migrating from rural areas to cities and metropolitan areas at an exponential rate. Currently around 50% of the world's population live in cities and this percentage is expected to reach 60% by 2030. In addition, cities at present account for around 60% of production machinery worldwide. As a result, their stake of resource consumption has reached around 60% and they account for 70% of the global carbon emissions. This exponential population growth and the corresponding industrialization revolution together have overloaded, and sometimes destabilized key infrastructure in numerous cities around the globe, according to the United Nations. This includes an increased number of slum inhabitants, inadequate sanitation systems, overloaded roads, deficient transportation, insufficient water supply, polluted air, and poor waste management, to name but a few. Hand in hand, these deficiencies as well as the rapid urbanization and the surge of industrialization in dozens of cities around the world have sparked an outcry for eco-efficient housing, manufacturing, energy supply, farming, transportation, and waste management. In this report, the term eco-efficiency refers to models, techniques, and practices that switch an economy or organization from unsustainable development to a sustainable development [b-Yadong]. Sustainability in this report means producing more products and services with less resources, waste, and pollution.

Currently, the global economy is heading rapidly towards the era of SSCs, where economies, social activities, and city governance are heavily reliant on collecting big data, and analysing it to make smart predictions and decisions [b-WEF]. United for Smart Sustainable Cities [b-U4SSC] defines a smart sustainable city as "an innovative city that uses information and communication technologies (ICTs) and other means to improve quality of life, efficiency of urban services, and competitiveness, while ensuring that it meets the needs of present and future generations with respect to economic, social, environmental as well as cultural aspects" [b-U4SSC]. SSCs employ innovations and technology to deliver more with less resources through maximizing use of resources to fulfil the needs of citizens, the economy, and the environment [b-WEF]. Smart cities also adopt measures to reduce pollution, develop renewable sources of energy, provide high quality fresh water, and extend sustainable drainage systems, in addition to smart mechanisms for managing all types of waste and emissions. It is important to note that the notion of SSCs is not limited to their particular territories and indeed has a global dimension. To be more specific, major challenges facing human society such as climate change, criminality, pollution, disease, poverty, wars, refugees, pandemics, and depletion of natural resources, together do not respect borders of cities or territories of countries [b-U4SSC]. These are typical priorities of SSC programs. In addition their objectives focus on enhancing the quality of life through smart education, high quality healthcare, Internet of things (IoT), big data, cloud computing and software as a service, intelligent transportation, smart buildings, smart manufacturing, and smart management of waste and emissions.

An ideal vision and expected outcomes of sustainable cities' programs include well-being, sustainability, transparency, economic development, efficiency and resilience, collaboration, and innovation [ISO]. ISO advocates a model of "smart city operating model" whose vision and expected outcomes are citizen centered [ISO]. Instead, we promote an implementation model that prioritizes sustainability requirements while fulfilling citizen needs. To be more specific, a typical service or product, business process, strategy, toolkit, vision, objective, measurement, or decision related to SSCs should integrate the following components:

1. All the 17 SDGs as a blueprint for people prosperity and sustainability of the planet; and
2. Environmental needs including emission reduction, reduced waste, preserving resources, and balancing between needs of current generation and future generations.

5.1 The role of artificial intelligence

In the consciousness of the United for Sustainable Smart Cities (U4SSC), a typical smart city should follow and adopt strategic guidelines to implement the New Urban Agenda, the Paris Agreement, Connect 2020 Agenda and the 2030 Agenda for Sustainable Development Goals, and particularly goal 11 [b-U4SSC]. To that end, such cities usually use emerging technologies such as Internet of things (IoT), artificial intelligence (AI) and big data [b-Alam]. Our report focuses only on the role of AI in achieving the 2030 Agenda for Sustainable Development Goals in the context of SSCs.

Progressively applications of artificial intelligence (AI) have emerged as effective enablers of key aspects of SSCs. These applications have become effective vehicles in serving almost every aspect of the daily life activities of smart communities. This includes increasing business efficiency, managing energy sources, optimizing land use, enhancing transportation, and sustaining the environment [b-Yigitcanlar]. The importance of AI for sustainable development stems from its capabilities to take poor, complex, and unstructured data and analyse it to identify needs, provide services and prevent crises [b-ITU]. In addition, AI has become an effective vehicle for backing evidence-based policy and informing decision making in a wide range of fields. Moreover, its applications have been used for improving employee wellness, managing energy, reinventing agriculture, improving traffic control, reducing air pollution, managing parking space, facilitating electronic commerce, and assuring security [b-Buttice].

In particular, AI applications are used to monitor environmental change; increase energy efficiency; reduce energy consumption of households; and optimize operations of smart transport systems [b-Yigitcanlar]. For example, smart transportation in smart cities utilize a variety of intelligent transportation systems (ITS), big data, and data analytics, machine learning, deep learning, IoT, and edge analytics [b-Ang]. These tools support and optimize (ride sharing), driver experience, autonomous vehicles, collaborative traffic control, and traffic flow prediction, [b-Ang]. Table 1 shows a framework for smart sustainable cities [b-WEF].

Table 1 – A framework for smart sustainable cities [b-WEF]

Theme	Governance and policy	Society	Infrastructure and services	Environment	Business & economy
	Urban planning	Public safety and security	Water	Air pollution prevention	Urban business environment
	City operations and finance	Health provision	Waste	Land protection and rehabilitation	Private sector investment
Issues	Citizen engagement	Access usage and completion of education	Mobility, transport and geographic accessibility	Water protection and rehabilitation	Development of a competitive economy
		Social inclusion	ICT connectivity	Biodiversity protection and rehabilitation	Green growth
		Demographic change	Energy and real estate	Urban resilience and adaptation to climate change	
			Education, health, social, community &recreational		

Sustainable development goals (SDGs) are a collection of 17 goals agreed upon by the United Nations General Assembly (UN-GA) in 2015 to be achieved by 2030. They serve as a "shared blueprint for peace and prosperity for people and the planet, now and into the future." Because of the diversity of goals of SSCs, we assume that a typical SSC is committed to achieving these 17 SDGs. We do not intend to cover all of these goals. Instead, this Technical Report is envisioned to show how AI applications contribute to some of these goals, measure their impact on SDGs, customize effective indicators and outline sustainable best practices and recommendations. The report is an attempt to guide current SSCs as well as future endeavours. We use the term SSCs to refer to both smart cities and smart communities, as dictated in the notion of SDG#11.

This document targets the following stakeholders:

1. City leaders and governors who want to align their vision and expected outcomes of their program with the SDGs;
2. Senior executives (including chief executives, sustainability commissioners, sustainability chief officers, chief information officers) who are searching for programs and initiatives to achieve sustainability related strategic goals;

3. Regulators who protect the interest of the planet, codify and enforce rules, and monitor compliance with sustainability obligations; and also standardization bodies which institute sustainability in the design and implementation of services, products, and business process;
4. Policymakers who provide recommendations and feedback to increase the impact of AI on sustainability and commissioners who oversee sustainability related programs;
5. Community innovators, software developers, educators, researchers, representatives, individual citizens, technologists, and environmentalists who are willing to be effective participants in saving our planet and sustaining its resources.

Therefore, it is important to explore the potential of AI technologies, current successful implementation models, outline plausible performance measures and recommend best practices with respect to SSCs. More specifically this report attempts to draft a framework for employing AI for achieving the ambitions of SDGs in the context of SSCs. It also features guidelines that may assist cities, with similar context and development needs, if they need to build on these successful cases. In this report, we discuss 6 cases of employing AI technologies for SSCs. We also highlight their social, economic, and environmental impact. In addition, we suggest best practices, measures and relevance to SDGs. Furthermore, we will place all these different factors in appropriate fields: such as agriculture, healthcare, transportation, education, manufacturing, etc.

6 Effective use cases

Table 2 lists the 17 sustainable development goals (SDGs) in brief.

Table 2 – Sustainable development goals (SDGs)

GOAL 1:	No poverty
GOAL 2:	Zero hunger
GOAL 3:	Good health and well-being
GOAL 4:	Quality education
GOAL 5:	Gender equality
GOAL 6:	Clean water and sanitation
GOAL 7:	Affordable and clean energy
GOAL 8:	Decent work and economic growth
GOAL 9:	Industry, innovation, and infrastructure
GOAL 10:	Reduced inequality
GOAL 11:	Sustainable cities and communities
GOAL 12:	Responsible consumption and production
GOAL 13:	Climate action
GOAL 14:	Life below water
GOAL 15:	Life on land
GOAL 16:	Peace and justice and strong Institutions
GOAL 17:	Partnerships to achieve the goals

Again the purpose of this document is to present a number of effective use cases employing AI for developing SSCs. The term "effective" in this report means to what extent AI applications are successful in achieving SDGs. Traditionally SSCs usually focus on SDG#11: "make cities and human settlements inclusive, safe, resilient and sustainable." Instead, this report considers all other relevant SDGs and extends beyond cities to include smart sustainable communities and rural societies as well. In particular, we will reflect on the impact of smart AI applications on achieving the millennium sustainable development goals (SDGs). These agreed upon SDGs are centered on achieving the economic, social, and environmental aspirations of sustainable development, as listed in Table 2.

6.1 AI and food security

The currbon ent world population has exceeded 7.6 billion and it is expected to rise to 9.8 billion by 2050 [b-ITU]. This exponential growth will put massive pressure on water, land, energy, and other natural resources [b-ITU]. In addition, the Russian-Ukrainian war puts more pressure on food and energy supply chains and exacerbates related problems. In this respect, there is a rapid deployment of IoT and AI in agriculture to optimize land yields, control water consumption, and efficiently exploit natural resources. In particular, IoT and AI have been effectively used for crop diseases containment, storage management, weed management, irrigation control, pollution reduction, water management, and pesticide control [b-Jha].

One of the consequences of climate change is the escalation of locust outbreaks in African and Asian countries [b-Salih]. In May 2018, an unusually powerful tropical storm hit the Arabian Peninsula, causing heavy rainfall that created vast desert lakes in Oman and Saudi Arabia. Similarly, a huge outbreak of locust hit 23 countries spanning from Tanzania to Pakistan in 2020. Warm weather, sandy land, and wet soil together constitute a perfect environment for desert locusts to hatch from eggs, causing a massive outbreak [b-Salih]. As with other natural disasters, locust plagues escalate the food security problem and disrupt food supplies as well.

It is reported that around 138 million US$ have been invested in traditional measures to contain locust outbreaks [b-Warner]. The estimated food loss however was around $9 billion which exacerbated food security in the infested countries which happened to be poor [b-GPAI]. One issue of traditional containment measures is their reactive nature. In particular, response teams usually start their efforts after the outbreak erupts and its destructive impact on crops and grazing pastures becomes evident. Another environmental harm of traditional measures is using pesticides for the entire plague and this method of control usually harms both other useful insects and pests and obviously this degrades biodiversity. Using chemicals to fight insects also has negative impact on food quality and also on the health of humans and animals.

6.1.1 Adopted AI technology

Precision agriculture employs advanced information and communication technologies (ICTs) to control and enhance crop and livestock farming. In particular, it uses global positioning system (GPS), control systems, sensors, robotics, machine learning, big data analytics, drones, autonomous vehicles, and other software in agriculture related activities [b-ITU]. In this respect, Kuzi is an AI based software developed by Selina Wamucii (a Kenyan agriculture company) in January 2021 to control locust infestations [b-Warner]. Kuzi is a machine learning based application that assists African farmers to control locust infestations by sending early warnings to farmers [b-Wamucii]. 'Kuzi' is a Swahili name for a locust-eating bird. The system is trained on a dataset collected through satellites, and sensors for factors that affect locust breeding, swarm formation, and its expected routes. Training data also includes information about surface temperature, soil moisture, wind, and humidity [b-Wamucii]. The system aggregates collected data and analyses it to produce useful information such as the course of the outbreak, the mapping of the plague, its routes, and its breeding index. It also predicts breeding time, location, and migration destinations. These predictions are analysed by experts and response teams to make recommendations and send timely warnings to farmers via text messages. Related warnings and alerts may be sent three months in advance of an infestation so that policy makers, response teams, and farmers can prepare suitable mitigation measures for the outbreak [b-Warner]. In other words, this proactive approach gives stakeholders enough time to prepare for the outbreak and effectively contain it [b-Warner].

Table 3 – Use of Kuzi to control pest outbreaks

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG No.
Healthcare/ environment	Poverty reduction	Reduced costs, increase crop yield	Decreased pollution, mitigating climate impact	Reduced pesticide doses	3, 11
Food industry	Food security	Responsible food production		Increased crop yield	2, 11
Economy	Poverty reduction			Cost reduction of pest control	2, 11
Agriculture		Sustainable agriculture	Preserving land	Saved farming land	2, 8

6.1.2 Impact on SDGs

Using AI technology to proactively predict locust infestations has proved to be a game changer.

A chief advantage of Kuzi is its proactive nature as it predicts the outbreak and fights it at its source before it erupts and harms vast areas of crops and grazing land. It also deals with it in a small area which means less environmental harm, limited degradation of crop quality, limited crop loss and lower costs of containment.

Using Kuzi to control pest outbreaks has a variety of positive economic, social, and environmental advantages, as presented in Table 3 and discussed below:

Social benefits

– **Poverty reduction:** Most of the food production in the world is produced by small farmers who usually suffer from poverty and food insecurity [b-ITU]. A large scale disruption of food production will severely harm vulnerable individuals in Africa, and more particularly in Somalia, Kenya, and Ethiopia, who already suffer from food insecurity problems [b-Melvin]. Locus plagues make things even worse and add more pressure on rural communities which already suffer from poor economic conditions and political limitations [b-Salih]. For instance, the outbreak of late 2019, destroyed 2,400 km^2 of pastureland in Kenya, 70,000 h of agriculture land in both Ethiopia and Somalia [b-Salih]. It is reported that a relatively modest swarm of 40 million individuals eats an amount of food equivalent to that required to feed 35 000 people per day and in a week, it will eat the food of 250 000 people [b-Melvin]. A large-scale disruption of food production will severely harm vulnerable individuals in Africa, particularly Somalia, Kenya, and Ethiopia, who already suffer from food insecurity problems [b-Melvin]. This is to say that using the Kuzi system to fight locust swarms will improve food security and eventually reduce poverty (SDG#1). It will also enhance sustainability and resilience of local communities (SDG#11).

Economic benefits

– **Minimizing cost:** Employing AI applications in agriculture optimizes operation efficiency and minimizes production costs [b-Eli-Chukwu] In addition, dealing with the outbreak in its early stages before locust eggs hatch also offers great savings. Farmers can also use lower doses in fighting campaigns and customized targeted areas. These modern technologies also optimize field crop yields, minimizing consumed fertilizer and preserving irrigation water [b-Eli-Chukwu]. The system appears to minimize both the containment cost as well as the cost of food production.

– **High quality crops:** Locust infestations frequently disrupt food supplies, particularly in Africa and Asia whose populations are mostly vulnerable. Unlike other types of pests, locusts invade agricultural land in very large and intense swarms whose size might exceed 40-80 million for a single swarm. A typical swarm of locusts can consume a quantity of crops that is enough to feed 35 000 individuals. This is to say that such outbreaks threaten food supplies and security. Controlling locust outbreaks decreases the size of swarms and infected areas. This leads to using less pesticides to fight locusts. Responsible resource use is a key practice in SSC [ISO].

– **New sources of food:** Some communities (e.g., in Sudan, Yamen, Saudi Arabia, Oman) eat locusts. An early detection and planning for the outbreak helps community members and response teams to decide if they should take the opportunity and harvest locusts for human consumption (SDG#2), use birds to control it, or deploy insectivorous birds to fight it.

– **Inspiring collaboration and innovation:** The Kuzi system is used in Somalia, Ethiopia, Kenya, and Uganda. International collaboration is required to transfer it to other countries in the Middle East and Asia (SDG#17). In addition, the company is working on extending it to agricultural support insurance service and this is a real example that shows how AI inspires innovation in food security (SDG#9). Recalling the definition of SSCs, these cities innovate to produce more with less resources [b-U4SSC].

Environmental benefits

– **Climate action:** Climate change has a significant impact on temperature, droughts, storms, and rains in terms of frequency, duration, and strength. Together, these conditions create fertile settings for locust breeding and locust outbreaks [b-GPAI]. Using the Kuzi system to control locusts is a climate action that mitigates the consequences of climate change (SDG#13).

– **Biological control of pests:** Large-scale use of biochemical solutions will definitely kill some useful worms and insects which will have a negative effect on biodiversity. If the plague is detected early, farmers could use bio-control interventions that may include insectivorous flocks of birds. This will eventually lead to improving biodiversity and life on land in general (SDG#15).

6.1.3 Recommendations and best practices

There is a growing adoption of AI systems to manage industries, farms, transportation, telecommunication, and lifestyle in modern societies. To effectively utilize this power for sustainable development, it important to adopt effective enabling policies, regulations, and best practices as follows:

– **Bridging the digital divide:** One key prerequisite for employing AI for development in Africa is to bridge the digital divide and make ICT accessible by all. In 2019, around 50% of the world population, mostly in Africa and Asia, did not have Internet access [b-ITU].

– **User interface:** Another challenge facing effective use of the Kuzi application is the need to develop a dynamic user interface that considers languages of local people. The application allows individuals to subscribe to its services in order to receive warning messages, news, and reports. Yet, Africa has many local languages and some of them are not written and it is difficult to serve all these languages. Therefore, it may be useful to incentivize standardization of application programming interfaces (APIs) for major local languages [b-ITU].

– **Multi functionality:** Another challenge is how to enhance this free application to offer other food security and sustainability related services. In other words, the question is how to augment AI technology and mobilize community knowledge for more multi-functional agriculture and food security related activities?

– **Secure funding:** Another challenge facing wide adaptation of AI for food security in developing societies is the lack of funding. Digital infrastructure requires huge investment that may not be available for small organizations and developing societies [b-GSR].

– **AI ecosystem:** It is also necessary to create the environment for employing AI for development. This environment or (ecosystem) includes governance institutions, data protection frameworks, sectoral regulatory frameworks, initiatives for international cooperation, adoption of international standards, policies and laws [b-ITU].

6.1.4 Similar applications

AI applications can be rapidly deployed to "reinvent agriculture" and bring in radical change to fight climate change. In particular, AI can increase efficiency and productivity in all stages of the agricultural value chain including distribution of seeds and fertilizer, weather forecasting, crop and soil monitoring, customer demand forecasting, and provision of real-time advice to farmers [b-ITU]. For instance, smart flying drones are used to collect massive amounts of environmental data about fields and crops that is later fed to smart machines (tractors, harvesting machines, etc.). Unlike human workers, machines can collect and analyse data in real-time and make complex decisions on the spot. These decisions may include choosing optimal fertilizer, improving efficiency, predicting crop performance, and maintaining sustainability [b-Buttice]. In the same context, smart devices have been used in farming to collect data through IoT, sensors, and satellite communications to assist in smart farming. For instance, AI applications have facilitated the formation of about 1 871 of cooperative (co-op) farming projects (serving 1 890 057 farmers) in the United States alone [b-Chukkapalli].

6.2 Managing flood disasters

Climate change has a notable impact on sea level changes, floods, tornados, hurricanes, and other natural disasters. Because of climate change, more people are expected to be exposed to floods in 59 countries, mostly in Asia and Africa. In 2020, a violent flood hit South Asian countries affecting nearly 10 million people. In particular, it destroyed crops and farmland of millions of people and enforced 9.6 million to evacuate [b-Alam]. In addition, it killed at least 550 people in Bangladesh, India, and Nepal. Therefore, disaster management efforts may have to find smart tools and novel approaches to mitigating such destructive disasters. Table 4 shows the impact of FloodAI on SDGs.

Table 4 – The impact of FloodAI on SDGs

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG
Healthcare	Reduced injuries, saving lives		Mitigate impact of climate change	Number of saved individuals	3, 6, 13
Agriculture		Sustainable agriculture, reduce loss of livestock	Preserving land	Saved farming land	2, 8
Real state and infrastructure		Saving assets	Mitigate disasters	Saved assets	3

6.2.1 Technology employed

AI systems have been successfully used to manage natural disasters. The United Nations Satellite Centre (UNOSAT) employs satellite images to manage natural disasters and uses AI to analyse related data. The system provides needed information and knowledge support for managing more than 20 floods per year. It employs AI applications and big data to coordinate preparedness and response activities during floods [b-UNOSAT]. In particular, it has used the FloodAI toolkit, see Table 4, for data collection and aggregation, analysis, prediction, and decision making. UNOSAT collaborates with local entities, humanitarian agencies and crises response committees on the ground. FloodAI collects data from operation facilities from a number of countries including Bangladesh, Cambodia, Mozambique, Myanmar, Nepal, Thailand, and Vietnam. The data is filtered, aggregated and analysed to be used for mitigation and response efforts.

In August of 2021, heavy rain continued for several days in Nepal, leading to a massive flood that triggered rivers to overflow, and caused landslides in many areas. Thousands of houses and informal buildings were destroyed. In addition, thousands of people were forced to stay in crowded and poorly prepared shelters.

6.2.2 Impact on SDGs

Effective management of natural disasters requires proactive measures to respond to them and mitigate their impact. There is an increasing adoption of AI technology to analyse disaster-related data and make related predictions. Natural disasters cause huge damage, mortality, and business loss. AI can provide the response team with the necessary information to understand natural threats, monitor the disaster in real time, and anticipate loss.

Economic benefits

– **Facilitating decision making:** The FloodAI system has assisted managers to extract information about estimated number of damaged houses, loss of farmland, and impacted individuals (SDG#8). This toolkit visualizes this information on dashboards to assist decision makers in their decision-making process. In addition, collected information is digitized in a way that could be extracted in paper format to inform reporting. Above all, this toolkit has increased by six the capacity of UNOSAT to process satellite images, compared to the traditional method of data capturing and analysis.

– **Minimizing damage:** An early detection of natural disasters assists response teams in controlling damage and loss, particularly when they warn people early and ask them to evacuate. Valuable assets and vulnerable resources can then be saved. In other words, it facilitates efforts that alleviate the consequences of climate change (SDG#13). Suggested KPIs to measure this impact include the number of saved individuals, and the value of saved assets and resources.

– **Business continuity:** Vital business operations could be moved to safe areas (SDG#8).

Social benefits

– **Decreasing mortality:** Early detection of the disaster enables response teams to set a plan for evacuation and mitigating loss. This may include providing instructions and directions about the best routes to evacuate the premises through the nearest exit and the nearest shelter. (SDG#3).

– **Disease control:** As mentioned previously, natural disasters destroy thousands of houses and kill many people. Survivors usually stay in crowded and poorly prepared shelters. These inadequate rescue efforts were violating COVID-19 prevention methods including lockdown and social distancing. This is to say that collecting data and managing disasters through face-to-face communication was difficult and risky. In addition, water-borne diseases may erupt during such disasters. In general, during such humanitarian disasters, many victims suffer from poor sanitation systems and insufficient clean water supplies. Therefore, using AI to detect natural disasters early enables rescue teams to prepare for them and lessens their consequences.

Environmental benefits

– **Mitigating impact of climate change:** One of the consequences of climate change is invoking natural disasters, including floods. FloodAI is a good example of employing AI to mitigate these disasters (SDG#13).

6.2.3 Recommendations and best practices

To unlock the potential of AI for disaster response, it may be useful for response teams and concerned entities to consider the following recommendations:

Table 5 – The impact of platooning on SDGs

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG
Urban planning	Wellbeing	Saving cost	Saving fuel	Saved fuel	11
Business	Safety and comfort	Costs reduction, reduced accidents, improved logistics,			14
Transportation		Reduced accidents, optimize traffic, reduced labour	Reduced emissions	Reduced labour, reduced CO2	14, 9
Healthcare	Reduced accidents				4

– Plausible best practice is developing multi-disciplinary partnerships and international collaboration that involves technologists, regulators, scientists, domain experts, policymakers, and developing agencies. Another best practice is to extend collaboration efforts between vulnerable communities (SDG#17). This collaboration may comprise data partnership, training and awareness, warnings, and technology development.

– Bridging the algorithmic divide with respect to infrastructure, training datasets, applications, models, and knowledge.

– Facilitating training to increase readiness and build capacity to transform traditional disaster recovery management to a new paradigm centered on AI.

– Inspiring open-source software developers and adopting programs to transform research into practical and commercial deployment.

– Addressing interoperability and data sharing issues: Intelligent transportation systems integrate data from different sources and operators such as mobile network operators and traffic departments. For privacy concerns and data ownership reasons, operators may not be willing to share this data [b-ITU].

6.3 Intelligent transportation systems

Transportation is an important means to conduct daily activities, particularly in cities. Roads transport around 70% of the freight tonnage in the United States of America (USA) and about 75% in the European Union (EU) [b-Sivanandham]. The growth of transportation in big cities increases congestion, fuel consumption, (road maintenance, and accidents), emissions, and labour [b-Sivanandham]. We use the term 'intelligent transportation systems' in this report to refer to systems, devices, and models that increase productivity of transportation while reducing the social, economic, and environmental costs of transportation. One aspect of intelligent transportation systems is to transform transportation means into a smart collaborative network whose nodes collect information and share it with others. One mode of such systems or networks is vehicle-to-vehicle (V2V) collaboration and vehicle-to-infrastructure (V2I) cooperation.

Platooning is a cooperative driving application for autonomous vehicles that optimizes fuel consumption and traffic efficiency. In particular, it enables a collection of vehicles to cooperate, coordinate, exchange information, and travel together in the same lane in a train-like manner [b-Bergebheim]. Table 5 lists some of the impacts of platooning on SDGs.

6.3.1 Technology employed

Platooning is defined as "the practice of driving vehicles closely to each other with automated driving systems and vehicle to vehicle (V2V) communication for coordinated actuation and control" [b-Sivanandham]. In this model, one driver controls a powerful vehicle that leads the platoon and pools a number of other vehicles. It relies on the driver assistance system that manages the inter-vehicular spacing, longitudinal control, and lateral control. The longitudinal controller coordinates breaking, and cruising velocity and the lateral controller manages steering, path selection and lane changes [b-Sivanandham].

In 2008, Japan started the Energy ITS which adapts the cooperative truck platoon for the purposes of fighting global warming, maximizing energy efficiency, and increasing road throughput [b-Tsugawa]. A typical platoon of the Energy ITS project in Japan consists of three fully automated trucks that drive together at 80 km/h with the gap of 10 m [b-Tsugawa].

6.3.2 Impact on SDGs

A number of benefits are accrued from employing AI in platooning transportation:

Environmental benefits of platooning

Platooning holds a wide range of environmental benefits [b-ACEA]:

– **Decreasing fuel consumption:** The essence of platooning is having one engine drive a number of vehicles. This will organize a number of vehicles to drive via one engine, at a steady speed, with less braking and rushing. This results in reduced fuel consumption (SDG#13).

– **Decreasing CO2 emissions**: Thanks to reducing the number of engines and drivers, it is reported that platooning may decrease CO2 emissions by up to 10 % (SDG#13) [b-Sivanandham]. It is important to note that each driver has a certain footprint in terms of paper consumption, supplies, and other forms of environmental cost. This is another environmental saving from adopting platooning (SDG#13).

Social benefits

Economic benefits gained from platooning transportation include [b-ACEA]:

– **Decreasing accidents:** Platooning improves traffic flow [b-Sivanandham] and decreases the rate of road accidents when one driver is equipped with an advanced driving assistant (ADA) and drives a few vehicles. Reports show that human errors are the main reason for about 90% of accidents. This contributes to improving road safety [b-Sivanandham] and work conditions (SDG#13) and health as well as mortality (SDG#3).

– **Improving work conditions:** Using the advanced driving assistant (ADA) system increases the convenience and comfort of driving. This means that a platoon in Japan spares two drivers (SDG#8). In addition, drivers who are following the leader may benefit from their time and undertake administrative work or conduct business related communications.

– **Improving safety:** Platooning increases the safety of drivers through automatic steady driving and braking with virtually zero reaction time compared to human braking (SDG#3).

– **Facilitating data collection:** A platoon is equipped with smart devices that can collect, analyse and predict road conditions and traffic related data.

Economic benefits

Economic benefits gained from this transportation mode include [b-ACEA]:

– **Improving efficiency:** Platooning improves efficiency of logistics when arranging shipment of a few vehicles in one process. It also optimizes supply chain and transportation through efficient use of roads, fast delivery of goods, and reduces traffic jams. In addition, it optimizes the productivity of labour (SDG#8).

– **Reducing fuel consumption:** Using one engine to pool few vehicles significantly reduces fuel consumption. Collected data shows that the platoon saves about 14% of energy consumption (SDG#13). Fuel consumption makes up to 30 % of the total operation cost of transportation. This is to say that platooning promotes what could be called 'sustainable responsible transportation' in which shipping costs and waste are minimal. Overall, the prices of final products and their environmental footprint will eventually decline as well (SDG#13).

  It is important to note that the benefits of platooning hold true for autonomous vehicles as well.

Recommendations and best practices

There are several best practices that may assist in promoting platooning, and smart transportation systems in general:

– **Change management:** Workers may resist the adoption of AI systems for a variety of reasons including fear of losing their jobs, loss of control, business disruption, lack of skills, and lack of trust in the new system [b-Power]. A good practice by managers and policymakers is to adopt an appropriate approach for change management. Another suggested practice is to engage employees through the entire life cycle of system implementation to realize its benefits and savings [b-Power].

– **System and infrastructure integration:** Smart transportation systems may perform well locally but not across borders. Vehicles that drive across countries' borders may encounter different traffic systems and different infrastructure that may not be compatible. Therefore, the success of such systems requires international or at least regional collaboration and partnership between different actors (SDG#17).

– **Improving infrastructure:** Smart transportation utilises data driven infrastructure and to facilitate data exchange, roads should be equipped with latest mobility technologies. This might not be available in poor neighborhoods, rural areas, and developing societies. Therefore, bridging the digital divide is not only important for smart transportation, but also for delivering SDGs (SDG#9).

6.3.3 Similar applications

Researchers at the Department of Energy's Lawrence Berkeley National Laboratory are working on a computational tool based on deep reinforcement learning models in their CIRCLES application – which stands for "Congestion Impact Reduction via CAV-in-the-loop Lagrangian Energy Smoothing" to smooth traffic in congested cities [b-Buttice]. The system simulates large amounts of vehicles driving in custom traffic scenarios. Therefore, it reduces energy consumption and improves traffic flow by reducing stop-and-go and controlling traffic jams. It also uses deep learning algorithms to analyse images with traffic information obtained from satellites, smartphones, IoT, and sensors.

6.4 Restoring biodiversity

Biodiversity in the Great Barrier Reef of Australia has deteriorated because of climate change that has sparked an outbreak of star fish. Swarms of star fish started to prey on coral reefs and degraded it significantly. Researchers from Queensland University of Technology have used a special AI enabled underwater drone called LarvalBot to restore it [b-Buttice]. During the coral breeding season, October and December, the corals release eggs and sperm which float towards the surface and is naturally fertilized. Environmentalists collected fertilized eggs and spread them on the ocean floor using the LarvalBot drone. To be more specific, they loaded the LarvalBot drone with hundreds of thousands of larvae, controlled them to identify degraded areas that needed restoration or resettlement and used the same LarvalBot drone to facilitate breeding. Eventually, they restored or developed new coral reef colonies. Table 6 shows the impact of the LarvalBot drone on SDGs.

Table 6 – The impact of LarvalBot on SDGs

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG
Business	Reduced accidents	Cost reduction, reduced accidents, improved logistics			14
Transportation	Safety and comfort	Reduced accidents, optimize traffic	Reduced emissions		14, 9

6.4.1 Technology employed

The LarvalBot is an underwater robot drone that has been designed for a specific task which is the preservation of coral reefs. It has been designed to consider the needs and requirements of both coral reef rescuers and corals as well [b-Cstwiki]. Developers have built their design on existing open source under-water robots after modifying them to fit the special needs of their applications. A successful model for smart sustainable cities should engage citizens, businesses and civil societies in the creation, delivery and use of city spaces and services [ISO]. Developing open source software is a typical example of citizen engagement.

6.4.2 Impact on SDGs

Table 6 presents the impact of LarvalBot on SDGs and the following is a brief discussion:

Social impact

There are some social implications of LarvalBot that deserve discussion:

– **Protecting workers:** Preserving biodiversity underwater is a heavy duty and a risky task. This is because it exposes rescuers to a wide range of risks such as shark attacks, diving accidents (arterial gas embolism, etc.), underwater fauna and flora, stings and poison of corals, equipment malfunctions, strong currents, or extreme weather conditions. Therefore, replacing human workers with machines minimizes all such risks and improves the overall work conditions (SDG#8). This impact can be measured by the reduction of the aforementioned risks.

– **Replacing human force:** Table 1 indicates that social inclusion is one of the societal dimensions of SSCs. However, as with other automation processes, using machines instead of humans will do away with many jobs [b-Aalst]. This is a negative social impact that needs to be considered while assessing the overall social impact of AI technology.

Economic impact

There are a number of economic benefits from using this robot:

– **Coupling the capacity of humans and machines:** Leveraging the capability of both humans and machines in preserving biodiversity is one benefit of employing the LarvalBot to save coral reef. Machines provide services remotely, in harsh conditions, and all through the day, while humans provide oversight. Human control and oversight augments machine capacity by thinking outside the box, considering the context, adopting to the surrounding environment, and dealing with abnormal conditions. Altogether, integrating human intelligence with machine intelligence improves system performance, increases productivity and also minimizes risk (SDG#8).

– **Reducing cost:** Underwater settings are very harsh and using robots in these settings instead of human labour is very cost effective (SDG#8).

– **Inspiring innovation:** Developers and environmentalists have created a new robot from existing open source robots and modified it to achieve its task (SDG#9). They also wrote guidelines on how to use it [b-Cstwiki].

Environmental impact

– **Preserving biodiversity:** One chief environmental benefit of the LarvalBot is restoring the coral reef and repairing consequences of climate change at a lower cost.

– **Controlling side effects:** Sometimes when attempts are made to tackle the consequences of climate change, some side effects may result. To avoid these side effects, developers have used reef safe materials and avoided using chemicals that might harm reefs. In addition, they used plastic and water-proof coatings to build the machine.

6.4.3 Recommendations and best practices

– **Establishing partnerships between academia and sustainability workers:** The LarvalBot robot was developed by students. This indicates that student work and research could be tailored to solve environmental and sustainability related problems. Partnership (SDG#17) facilitates mobility and integration of resources of a wide spectrum of stakeholders to trigger climate actions and feed sustainability. Shared use of common resources, citizen engagement, and partnerships are key ingredients in a successful SSC implementation model [ISO].

– **Promoting open source algorithms:** Advanced AI applications are expensive and need skillful individuals to develop, operate, and maintain them. Developing societies and small organizations, in particular, often lack the necessary financial resources and AI knowledge. Therefore, promoting open source algorithms and applications can ease such problems (SDG#17).

6.5 Smart energy grids

The exponential growth of connected devices and emerging AI applications increases power consumption and CO2 emissions as well. Fossil fuel remains the main source of energy worldwide and this source of energy is responsible for the largest amount of CO2 emissions. To reduce emissions, it is necessary to reduce consumption of fossil fuels. The exponential growth of CO2 emissions is the main driver of global warming which has a wide range of catastrophic consequences. Fortunately, AI applications are expected to revolutionize the energy sector. In particular, AI has emerged as a powerful engine for reducing CO2 emissions and for assisting organizations and individuals overcome the consequences of climate change. It can collect big data and analyze it to inform energy initiatives, policies, strategies, and demand forecasting [b-Rolnick]. One famous application or platform of AI in this vital sector is called 'smart grids'. A smart grid (SG) is defined by the EU commission Task Force for Smart Grids as "an electricity network that can cost-efficiently integrate the behaviour and actions of all users connected to it, generators, consumers and those that do both, to ensure a low-loss, economically viable, sustainable power system with high quality and security of supply" [b-EC]. Table 7 shows the impact of smart grids on SDGs.

Table 7 – The impact of smart grids on SDGs

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG
Business		Cost reduction, better work environment		Reduced cost	8
Energy	Improved social welfare	Reduced accidents, optimize traffic	Fair tariffs		9 and 13

6.5.1 Technology employed

Utility companies have started to employ a wide range of smart technologies to build smart grids. For instance, they use IoT devices to collect real-time information to be used to reduce waste, rationalize consumption, enhance grid efficiency, optimize storage, and adopt methods for predictive infrastructure maintenance [b-Buttice]. Power supply can be adjusted automatically, leading to important savings, secure supplies, and fewer outages [b-Buttice]. Other technologies used in smart grids include artificial neural network (ANN) algorithms, reinforcement learning (RL), genetic algorithm (GA), and multi-agent system techniques. Used AI techniques include stochastic mixed-integer programming (SMIP), evolutionary algorithm, zero-knowledge proof, pedersen commitment, lightning search algorithm, polak–Ribiére gradient back propagation networks (PRGBNNs), gradient with descent adaptive learning rate momentum backpropagation, diffusion strategy, and consensus algorithm. For a thorough discussion of these algorithms, we refer readers to [b-Ali] and [b-Rolnick].

6.5.2 Impact on SDGs

As shown in Table 7, there are a number of social, environmental, and economic benefits of smart grids (SG).

Social benefits

There are some social gains from employing AI in smart grids:

– **Improved social welfare:** AI also increases the social welfare of the grid [b-Ali].

– **Better working environment:** The offerings of AI in the domain of SGs improve work conditions (SDG#8) when we equip professionals with the necessary tools to manage both energy supply and demand. AI also facilitates related processes such as managing renewable energy resources, integrating energy storage systems, forecasting demand, managing home energy, and securing the grid [b-Ali].

Environmental benefits

There are a wide range of environmental benefits of SGs:

– **Reduced emissions:** Reducing emissions in the energy sector requires switching low-carbon energy sources (e.g., wind, solar, hydro) and reducing emissions from carbon-emitting sources such as fossil fuels [b-Rol]. AI can facilitate these processes by informing deployment, grid operation, and research [b-Rol]. AI facilitates related processes such as managing renewable energy resources, integrating energy storage systems, forecasting demand, managing home energy, and securing the grid [b-Ali]. All together, these benefits contribute to SDG#13. Plausible KPIs include the percentage of renewable energy integrated in the grid and the percentage of power savings.

– **Responsible consumption and production:** In a smart grid consumption, production and waste will decrease. This is to say that SG techniques promote responsible consumption and production (SDG#12).

– **Increased efficiency:** Smart grid techniques will eventually reduce CO2 emissions. Decreasing CO2 emissions is a key climate action (SDG#11). The KPIs that may be used to measure this impact are the average power saving per customers and the increased production efficiency.

– **Enhanced reliability and security:** The distributed nature of SGs and the broad spectrum of its data sources make it vulnerable to attacks of hackers and intruders. They may compromise the privacy of customers, disrupting the system, alter its operation, or maliciously control the devices in connected homes [b-Ali]. Deep neural network algorithms are used to mitigate such threats. AI algorithms are also used for fault detection and security analyses. They also enhance the overall reliability of the system through real-time monitoring, fault detection, timely maintenance intervention, and effective integration of renewable energy sources [b-Ali]. Together, they significantly reduce waste of resources consumed during system interruption or restoration. They also make the grid, and the city, safer and more resilient (SDG#11).

– **Informing policies and decision-making:** SGs employ special algorithms and smart techniques to facilitate data classification, predictive maintenance mechanisms, demand/load forecasting, yield optimization, networking, and control strategies [b-Ali]. IoT is used to collect vast amounts of related data and this data is fed into special algorithms that facilitate these operations [b-Ali]. It also analyses consumer and producer data to instrument appropriate policy incentives and to optimize decisions that minimize both consumption and power generation, which eventually reduce CO2 [b-Ali].

Economic benefits

Employing smart grid techniques and algorithms has the following economic benefits [b-Buttice], and [b-Ali]:

– **Reducing production cost:** The overall distributed SG uses AI techniques to optimize controllable loads, and this results in cost reduction [b-Ali]. Adopting such technologies and the insights generated from collected data could optimize supply efficiency [b-Buttice]. It is estimated that SGs can save from $237 billion to $813 billion in the US alone. Hence, SG algorithms improve affordability of energy and promote clean energy (SDG#7).

– **Lower and more fair energy tariff:** By using smart applications, customers can tailor their energy requirements in a way that minimizes consumption and energy bill (SDG#7). To augment the benefits of SG, the United Kingdom was planning to install 53 million electricity and gas smart meters in homes and small businesses by 2020 [b-Buttice].

6.5.3 Recommendations and best practices

The following are some related recommendations that may be useful:

– **Standardization:** SGs require a wide range of standards. For instance, they need a standard for harmonizing power line carriers for appliance communications in the home. They need a standard, or a common information model (CIM), for collecting, storing, and sharing energy use information. They also need a standard to regulate network communications and cybersecurity. For a wide range of required standards, readers may consult [b-Annabelle].

– **Collaboration:** Distributed SGs have different stakeholders (e.g., consumers, producers, distributors, and policymakers) who might have conflicting interests. Therefore, there is a need for a framework that guides collaboration between them and outlines a common roadmap or vision about employing them for sustainability [b-Annabelle].

– **Testing and certification:** Testing different components of SGs is needed to help fix bugs and patch vulnerabilities. There is also a need for a certification framework to certify actors which are committed to SDGs. Testing, certifications, and related standards should ensure that there are no vulnerabilities in the system through which adversaries can penetrate it and conduct distributed denial of service attacks [b-Annabelle].

– **Fair pricing:** In order for consumers to enjoy the benefits of SGs, there is a need for fair pricing schemes that distinguish between regular consumers and industrial consumers [b-Ali]. In addition, consumers should have the power to reshape related policies and enjoy the gains offered by AI for the SGs.

6.6 Smart knowledge management

In the current knowledge-based society, knowledge has become a valuable asset as with other assets such as human resources, cash, brands, and customers. One of the great challenges facing western societies is the rapidly aging population. This means the number of individuals who retire is less than the number who join the job market. Retired people take away their knowledge and expertise with them, while newcomers usually lack domain specific knowledge. Therefore, retaining or sustaining the knowledge and expertise of aging workers has become key for communities, organizations, and societies to grow, compete, and innovate.

In this respect, the energy sector in the USA is one of the knowledge intensive sectors that is suffering from the phenomenon of rapidly aging workforce [b-Buttice]. It is predicted that around 25% of its employees will retire within five years. In the long run, this will lead to neutralizing their skills and losing their expertise. Therefore, there is a need for a solution to this great challenge.

Table 8 – The impact of Maximo equipment maintenance assistant system on SDGs

Industry/field	Social impact	Economic impact	Environmental impact	KPIs	SDG
Resources and material		Cost reduction,	Saving parts and repair resources	Lifetime of assets	13
Business management	Work environment	bridging knowledge gap, business continuity		Number of trained employees, Reduced errors, employee satisfaction	8, 9
Energy	Safety and comfort	Less cost	Reduced power consumption	Reduced CO2	13

6.6.1 Technology employed

AI plays a key role in capturing, storing, analysing, sharing, and utilizing knowledge [b-Al Mansoori]. To face the growing aging problem, IBM has adopted a special knowledge management technique to harvest the tribal knowledge of senior experts and feed junior workers whose job is to control power consumption of its famous IBM Watson AI. Tribal knowledge is "the collective wisdom of the organization and the sum of all the knowledge and capabilities of all the people" with respect to a specific product, process, or problem. It is usually earned through informal channels and treasured in the mind of experienced workers who usually gain it over time. It is also known as the tacit knowledge, institutional knowledge, intangible knowledge, or legacy knowledge of organizations.

IBM has developed the IBM Maximo Equipment Maintenance Assistant system to harvest the tribal knowledge of Watson experts. The system also uses machine learning techniques and cognitive tools to collect knowledge related to maintaining assets of IBM Watson AI. Fortunately, AI can augment the workforce by employing natural language processing (NLP) and pattern recognition algorithms to mine unstructured and structured data [IBM]. The system captures massive amounts of data and analyses it to generate insights, learned lessons and best practices. These outcomes could be used to train and guide newly hired employees and low skilled workforce [b-Buttice]. The Maximo Equipment Maintenance Assistant system has adopted what is called "the tribal knowledge" model through which knowledge of experienced workers is transmitted to the next generation of employees [b-Buttice]. The system collects feedback and inputs from employees and uses ML algorithms to analyse this data to provide recommendations to technicians and operators on how to effectively maintain equipment, how to accelerate productivity of workers and how to enhance their safety [b-Buttice]. To be more specific, it assists them with respect to repair techniques, maintenance, procedures, and techniques, ensuring optimal first-time fixes (FTF), detecting failure patterns, extending the life of critical assets, and reducing mean time to repair (MTTR) [IBM].

6.6.2 Impact on SDGs

Table 8 summarizes the social, economic, and environmental benefits discussed below:

Environmental benefits

– **Reduced emission:** When the system controls power consumption, it eventually reduces emissions (SDG#13). A typical KPI for this particular impact is to measure the amount of reduced CO2.

– **Efficient maintenance:** It is used to obtain insights and guidance to improve asset repairs, detect failures, optimize performance of equipment, and increase operational efficiency [IBM]. This will decrease frequency of replacing parts and extend the life of assets. As a result, this will save resources needed for new parts. This is another climate action (SDG#13) with respect to knowledge management, energy control, and resource usage. Saving resources has a positive impact on life on land. This could be measured by to what extent life of assets has been extended.

Social benefits

– **Bridging the knowledge gap:** The rapid aging of the workforce creates a knowledge gap where knowledge is dominated by senior workers, but junior ones lack such knowledge. Unlike human capacity, the power of ML algorithms stems from their capability to analyse structured and unstructured data and capture knowledge embedded in both for the purposes of educating junior employees. This benefit improves working conditions (SDG#8) and make IBM stronger (SDG#16).

– **Bridging the data divide:** IBM can afford necessary IoT devices and AI applications that create a massive knowledge ecosystem that integrates data and information from all connected devices and individuals. Its system targets data and insights that have been effectively used to minimize power consumption of IBM Watson AI. This is to say that it is possible to transfer learning and related insights from high-data settings to low-data settings if all grids share the same core system physics [b-Rolnick]. It has a positive impact on productivity (SDG#8) and responsible production (SDG#12).

– **Building the sense of community:** When knowledge is transferred from those who know to those who do not know, we are building a sense of community, or are transforming the workforce into a learning community (SDG#11).

Economic benefits

– **Reducing cost:** The Maximo system has reduced the operation cost of maintaining IBM Watson AI assets. In addition, it has reduced the cost of knowledge management and professional development.

– **Business continuity:** Functions of the Maximo system include ensuring optimal first-time fixes (FTF), detecting failure patterns, extending life of critical assets, and reducing mean time to repair (MTTR). All together, these features help technicians sustain business operation and avoid system failure. This is to say that it makes IBM strong, reliable (SDG#14) and more productive (SDG#8).

It is important to note that the aging population phenomenon is not limited to the United States or the energy sector only, but it is a great challenge facing all sectors and all western societies. This is to say that effective knowledge management schemes could be adopted in different sectors and on a general societal level. For instance, smart knowledge management can play a significant role in smart transportation through employing shared knowledge and information to facilitate smart mobility and promoting bicycling as an eco-efficient transportation mode [b-Thompson]. This eventually softens traffic congestion (SDG#9), decreases pollution (SDG#13), and improves health and quality of life at large (SDG#3). Poor air quality alone costs the Indian society around $95 billion per year [b-Thompson]. It can also enhance healthcare delivery when infected individuals share their experience with each other [b-Thompson].

Currently, more than two thirds of transportation emissions come from road transportation [b-Schaeffer]. Strategies to reduce transportation related CO2 emissions include reducing vehicle activities; switching to alternative power sources; improving transportation efficiency; and shifting to lower-carbon options. For further discussion on the role of AI in reducing transportation emissions, readers may consult [b-Rolnick].

6.6.3 Recommendations and best practices

Knowledge harvesting, mining, and utilizing sustainability related implicit knowledge can revolutionize each SDG and can also flourish in every single application domain of AI. To pursue this opportunity, stakeholders may consider the following recommendations:

– **Collaboration:** The tribal model for knowledge management assumes that current workers have expertise and knowledge that needs to be captured and shared. However, small organizations and developing societies might not have such knowledge or expertise. Therefore, international partnership and collaboration (SDG#17) on knowledge management should be on the priority list of standardization bodies and the units of the United Nations as well.

– **Intellectual property rights:** The system harvests, mines, and shares the implicit knowledge of senior technicians and developers. Therefore, for team members and organizations to share their knowledge, there must be an incentive mechanism or a framework for protecting intellectual property rights of workers. Senior workers and experts might be reluctant to share their knowledge without such incentives or protection mechanisms.

– **A framework for knowledge management:** It is recommended to develop a universal ecosystem or framework for harvesting implicit knowledge related to smart AI applications and use cases, SDGs and SSCs as well. This ecosystem should benefit from knowledge of private organizations, public entities, climate groups, activists, standardization bodies, and technologists.

7 Conclusion

Ultimately, employing AI for sustainable development requires a national strategy that considers existing opportunities, regulatory practices, challenges, implementation mechanisms, budgeting, and stakeholder engagement, readers may consult [b-ITU]. Developing societies (e.g., remote and rural communities) must overcome what is called "datafication". In other words, they must improve their capacity to digitize services and produce data, information, and knowledge from digitization. They also need programs and initiatives to increase accessibility and to update outdated data [b-ITU]. Another challenge that must be tackled is the bias, errors, and lack of transparency of AI algorithms [b-ITU].

The aforementioned recommendations and best practices should not be considered the sole and comprehensive blueprint for employing AI for SSCs. Such recommendations should be adjustable enough to accommodate local context, size of the organization, used system or application, and local regulatory system and laws. It is also important to convene a multi stakeholder partnership involving the government sector (e.g., education, energy, telecommunication, finance and planning authorities, health ministry, agriculture, transportation, etc.), private organizations, international development, municipalities, and civil society [b-GSR]. However, developing countries do not have the capacity to effectively deploy the AI and data revolution to yield sustainable development. They usually lack necessary infrastructure, funds, know-how, talents, and data needed for development activities.

Nevertheless, the hope is that this framework will guide efforts that focus on measuring the impact of AI on SDGs and the social, economic, and environmental objectives of SSCs as well. It is also hoped that scholars and experts would build on this framework to develop a more rigorous framework for an AI-driven sustainable ecosystem.

Bibliography

[b-ITU-T Y.4900] Recommendation ITU-T Y.4900/L.1600 (2016), *Overview of key performance indicators in smart sustainable cities*.

[b-ISO 37101] ISO 37101:2016, *Sustainable development in communities – Management system for sustainable development – Requirements with guidance for use*.

[b-Aalst] Aalst, Wil M.P. van der (2021), *Hybrid Intelligence: to automate or not to automate, that is the question. International Journal of Information Systems and Project Management: Vol. 9*: No. 2, Article 2.

[b-ACEA] ACEA, *What are the benefits of truck platooning*? Accessed from https://www.acea.auto

[b-Alam] Alam, J. and Hussain (2022), *W, Severe flooding in South Asia displaces more than 9.6 million people*, accessed on October 25th, from https://www.theglobeandmail.com/world/article-severe-flooding-in-south-asia-displaces-more-than-96-million-people/

[b-Al Mansoori] Al Mansoori, S., Salloum, S.A., & Shaalan, K. (2021), *The impact of artificial intelligence and information technologies on the efficiency of knowledge management at modern organizations: a systematic review*. Recent advances in intelligent systems and smart applications, pp. 163-182.

[b-Ali] Syed Saqib Ali and Bong Jun Choi, *State-of-the-Art Artificial Intelligence Techniques for Distributed Smart Grids: A Review, electronics*.

[b-Ang] Ang, Kenneth Li-Minn, et al. (2022), *Emerging technologies for smart cities' transportation: geo-information, data analytics and machine learning approaches*. ISPRS International Journal of Geo-Information 11.2: 85.

[b-Annabelle] Annabelle, *L. NIST and the Smart Grid*. January 2010. Available online: https://csrc.nist.gov/CSRC/media/Presentations/NIST-and-the-Smart-Grid-Presentation/images-media/nist-and-smart-grid_ALee.pdf (accessed on 12 May 2020).

[b-Buttice] Buttice, C (2022), *Top 14 AI Use Cases: Artificial Intelligence in Smart Cities*.

[b-Chukkapalli] Chukkapalli, S. S. L., et al. (2020), *Ontologies and Artificial Intelligence Systems for the Cooperative Smart Farming Ecosystem*, IEEE Access, Volume 8.

[b-Cstwiki] Retrieved from http://cstwiki.wtb.tue.nl/index.php?title=PRE2019_3_Group17

[b-GPAI] *Climate Change and AI, Recommendations for Government Action, Global Partnership on AI Report In collaboration with Climate Change AI and the Centre for AI & Climate*, accessed on May 20th, 2022, from https://www.gpai.ai/projects/climate-change-and-ai.pdf

[b-EC] *European Commission. Smart Specialisation Platform – Smart Grid*. Available online: https://s3platform.jrc.ec.europa.eu/smart-grids (accessed on 08 February 2023).

[b-Eli-Chukwu] Eli-Chukwu, Ngozi Clara (2019), *Applications of artificial intelligence in agriculture: A review*. Engineering, Technology & Applied Science Research 9.4, pp. 4377-4383.

[b-GSR] Global Symposium for Regulators (GSR) 2021, *Best Practice Guidelines Regulatory uplift for financing digital infrastructure, access and use*.

[b-ITU] Emerging technology trends 2021: *Artificial intelligence and big data for development 4.0*.
Geneva: International Telecommunication Union, 2021.

[b-Jha] Jha, K. Doshi, A. Patel, P. and Shah, M. (2019), *A comprehensive review on automation in agriculture using artificial intelligence*, Artificial Intelligence in Agriculture, Volume 2, June, pp. 1-12.

[b-Kibria] M.G. Kibria, K. Nguyen, G.P. Villardi, O. Zhao, K. Ishizu, and F. Kojima (2018), *Big data analytics, machine learning, and artificial intelligence in next-generation wireless networks*, IEEE Access, vol. 6, pp. 32328-432338.

[b-LarvalBot] LarvalBot underwater drone will reseed coral reefs damaged by climate change, March 2, 2020, accessed from https://www.digitaltrends.com/cool-tech/underwater-drones-coral-spawn/

[b-Melvin] Melvin, M. (2020), *Desert Locust Plague 2020: A Threat To Food Security*, accessed from https://www.foodunfolded.com/article/desert-locust-plague-2020-a-threat-to-food-security

[b-Power] B. Power, February 25, 2018, *How to Get Employees to Stop Worrying and Love AI*, Harvard Business Review, accessed on 7th of October 2022, from https://hbr.org/2018/01/how-to-get-employees-to-stop-worrying-and-love-ai

[b-Rolnick] Rolnick, D. et al. (2022), *Tackling Climate Change with Machine Learning*, ACM Computing Surveys, Volume 55, Issue 02 March 2023, Article No. 42, pp. 1–96.

[b-Salih] Salih, A.A.M., Baraibar, M., Mwangi, K.K. et al. (2020), Climate change and locust outbreak in East Africa. Nat. Clim. Chang. 10, pp. 584–585. https://doi.org/10.1038/s41558-020-0835-8

[b-Schaeffer] R. Schaeffer, R. Sims, J. Corfee-Morlot, F. Creutzig, X. Cruz-Nunez, D. Dimitriu, and M. et al. D'Agosto. Transport, in IPCC, Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Climate Change 2014: Mitigation of Climate Change, chapter 8. Geneva [O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlomer, C. von Stechow, T. Zwickel, J.C. Minx, (eds.)]. ¨ Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014.

[b-Sivanandham] Sivanandham, S. and Gajanand, M.S. (2020), *Platooning for sustainable freight transportation: an adoptable practice in the near future*? Transport Reviews, Volume 40, Issue 5, 2020, Pages 581-606.

[b-Thompson] A. Thompson, (2021) *The Potential for Knowledge Management in Smart Cities*, Jun 22.

[b-Tsugawa] S. Tsugawa, S. Kato and K. Aoki (2011), *An Automated Truck Platoon for Energy Saving*, IEEE/RSJ International Conference on Intelligent Robots and Systems (CD-ROM), 201

[b-U4SSC] The United for Smart Sustainable Cities (U4SSC), accessed from https://olc.worldbank.org/system/files/T-TUT-SMARTCITY-2017-PDF-E-Part1.pdf

[b-UNOSAT] *Flood AI Dashboards for Nepal: The Creation of a One-Stop-Shop For Real-Time Evidence-Based Decision-Making*. available online: https://www.unitar.org/about/news-stories/news/unosat-flood-ai-dashboards-nepal-creation-one-stop-shop-real-time-evidence-based-decision-making (accessed on February 23, 2023)

[b-Wamucii] Selina Wamucii (2023), *Using Artificial Intelligence to avoid the next locust plague*, accessed from https://www.selinawamucii.com/kuzi/, on February 23.

[b-Warner] Warner, K. (2021), *African farmers use AI to prepare for locust swarms up to three months in advance*, from https://www.thenationalnews.com/world/africa/african-farmers-use-ai-to-prepare-for-locust-swarms-up-to-three-months-in-advance-1.1143676

[b-WEF] Smart at Scale: Cities to Watch 25 Case Studies, World Economic Forum, Community Paper, August 2020.

[b-Yadong] Yadong, Y (2013), *Eco-efficiency trends in China*, 1978-2010: decoupling environmental pressure from economic growth. Ecological Indicators. 24: 177-184.

[b-Yigitcanlar] Yigitcanlar, Tan, et al. (2020), *Contributions and risks of artificial intelligence (AI) in building smarter cities: Insights from a systematic review of the literature*. Energies 13.6: 1473.

[b-Zaheer] Zaheer A., Zaynah A. Dhunny (2021), *On big data, artificial intelligence and smart cities*. https://www.academia.edu/81147146/On_big_data_artificial_intelligence_and_smart_cities?f_ri=977