Addo, Peter Martey; Baumann, Dominik; McMurren, Juliet et al.

Book

Emerging uses of technology for development : a new intelligence paradigm

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FEBRUARY
2021 | N° 6

Emerging Uses of Technology for Development: A New Intelligence Paradigm

Policy Paper

AFD éditions
AGENCE FRANÇAISE DE DÉVELOPPEMENT

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Key words: New Intelligences, Emerging Technologies, Value Propositions, Risks, Sustainable Development, Governance, Tech4Good

Abstract: With only ten years left to achieve the Sustainable Development Goals (SDGs), development organizations rapidly need to innovate their approach to decision making and problem solving. New lessons and understandings, born from emerging uses of technology, can enable these innovations. This position paper uses the new paradigm of intelligence—which includes data intelligence, artificial intelligence, collective intelligence, and embodied intelligence—to provide development practitioners, policymakers, and decision-makers with an overview of the benefits and risks associated with various emerging uses of technologies. These assessments are illustrated where possible with examples from the field. It recommends the creation of a decision-making framework to help practitioners determine whether to invest in emerging technologies and how such technologies can effectively support development objectives. This early framework iteration focuses on carefully defining the relevant development objectives while taking into account the prevailing environment before addressing the solution by assessing the maturity, challenges, cost implications and risks of the technology's use as well as the presence of enablers or disablers that could determine its impact and appropriateness.

Acknowledgements: This position paper would not have been possible without the support and expert guidance from our collaborators at the Agence Française de Développement, in particular Thomas Mèlonio, Alexis Bonnel, Sandrine Boucher, Jean Millerat, and Sarah Marniesse. We would like to extend our gratitude to Daniel Kaplan for his support and contribution.

At The GovLab, we would also like to acknowledge and thank Mary Ann Badavi and Michelle Winowatan for their important research support.

We are also grateful to the peer reviewers who provided invaluable input on a semi-finalized draft, including Sean Audain, Abel Pena, Jane Thomason, Eleanore Fournier-Tombs, Lawrence Kay, Lauren Maffeo Peter Dolch, Gemma Cassells, Travis Heneveld, Xoán Fernández García, Natalia Domagala, Vineet Singh, Rachele Hendricks Sturrup, Tracey Li, Harry Wilson, Ethar ElTinay, Jeremy Greenberg, Jeff Wright, Dominique Diouf, Prakhar Mehrotra, Roxana Radu, Gautier Uchiyama and Sofia Silvia Carballido.

Highlights

- **Under specific conditions outlined in this paper, the emerging uses of technology can generate four forms of intelligence (4Is)** that have the potential to improve development decisions and accelerate progress towards the Sustainable Development Goals (SDGs). These are:
  - **Data intelligence,** use cases reliant on datafication and analytics. It involves the use of technologies such as open data, data collaboratives, and the internet of things;
  - **Artificial intelligence**, use cases reliant on advances in computing power. It involves the use of technologies such as machine learning and expert model systems;
  - **Collective intelligence,** use cases reliant on group interaction and improvements in communications. It involves the use of technologies such as co-creation and crowdsourcing systems, smarter crowdsourcing tools, digital citizen assemblies, and open innovation platforms; and
  - **Embodied intelligence,** use cases reliant on the use of artificial intelligence in the physical world. It includes technologies such as robotics, unmanned aerial vehicles, and 3-D printers.
- **These forms of intelligence can help improve the decision-making capacity of development practitioners by enabling them to better understand or communicate relevant insights.** When implemented effectively and appropriately, new forms of intelligence can be used to fill information gaps; clarify the causes of successes or failure, or improve accountability, participation and transparency. They can also help individuals and communities increase their skills; provide new and more efficient services; and build interpersonal networks to empower the marginalized. This paper

outlines considerations and contextual factors that can play a role in the success or failure of such efforts.

- **It is critical to consider the risks associated with emerging uses of technology.** The intelligence paradigm poses several risks. These include: advancing technological determinism, exacerbating inequality, undermining transparency, and enabling political manipulation. There are some ethical issues that are closely connected to emerging technology, such as trust, knowledge, privacy, and individual autonomy. Furthermore these issues take on a heightened concern when the technologies in question are financed in a for-profit context.
- **To achieve community benefits through these new forms of intelligence, development practitioners must weigh potential benefits against risks in ways that involve all interested parties. Should benefits outweigh the risks,** these parties must then work together toward developing local capacities, promoting beneficiary ownership, and enabling responsible, de-risked implementation**.**
- **The decision-making framework introduced in this paper can be used to assess whether to invest in emerging technologies and if such technologies can effectively support development objectives.** This framework calls for carefully defining the development objectives, taking into account the prevailing environment before focusing on the solution, assessing the maturity of the technology, the challenges, cost implications and risks of the technology's use as well as the presence of various enablers or disablers that could determine its impact and appropriateness.

Introducing a New Framework to Consider Emerging Uses of Technology for Development: The Intelligence Paradigm

In 2015, the United Nations General Assembly set forth the SDGs, a series of 17 goals related to poverty, inequality, and climate change meant to be achieved by 2030.[1] Meeting them by this deadline requires innovation in how we make decisions and solve problems. Global challenges such as climate change, pandemics and poverty are complex and there is little time to rectify them. The urgency of these challenges not only demands innovative solutions but also innovation in how we develop solutions and make decisions. This position paper focuses on how the development practitioners can leverage new and emerging uses of technology to improve people's lives. It defines emerging technologies as digitally stored information and the computation of it, whether by machines, organizations, people, or markets. This collective use of information, alongside machine computation, creates the intelligence needed to make better decisions. While developing countries often have had less access to technologies and skills training, preventing them from benefiting from new innovations, careful investments can help reduce this inequity and empower locals to solve old problems in a new way.

New forms of intelligence, born from emerging uses of technology, have the potential to improve decision-making, problem-solving, and, as a consequence, how development goals are met. It can allow the application of what Bernard Stiegler calls the "economy of contribution," a system in which labor is no longer defined by the market but by the otium, the capacity to imagine and realize alternative solutions, of the people.[2] Novel uses of existing and emerging technologies generate forms of intelligence that, used separately or together, can improve how development actors promote

1 United Nations. "Take Action for the Sustainable Development Goals." United Nations Sustainable Development (blog). Accessed December 4, 2020. https://www.un.org/sustainabledevelopment/sustainable-development-goals/.

2 Stiegler, B. For a new critique of political economy 2010

better governance, identifying innovative solutions to pressing problems.

This paper is intended to introduce the four forms of intelligence and help personnel at development-focused institutions (hereafter referred to as " development practitioners") make decisions about the responsible use of associated technologies.

Through appropriate design and responsible implementation, development organizations can ensure the countries and communities they work in benefit from emerging uses of technology while mitigating the risks associated with their use. Determining whether to invest in technologies depends on a set of contextual factors, including the risks they could introduce to various stakeholders, the maturity of the technology, the challenges and cost implications of the technology's use, and the presence or absence of several enablers that could determine its impact and appropriateness in a given environment. This approach can be used in parallel with other frameworks and tools such as UN OCHA's *Peer review framework for predictive analytics in humanitarian response*.[3]

In the following pages, we summarize the role that the 4Is can play in improving development outputs and outcomes and achieving sustainable development goals. We start by introducing the 4Is the associated technologies that support their use in the development context, and some illustrative real-world use cases. Next, we assess the value propositions of these new forms of intelligence for development. We then identify key factors and considerations that affect the use of emerging forms of intelligence – including challenges and risks, determinants of contextual appropriateness, and enablers of success. Finally, we share a set of recommendations for development practitioners to help guide their selection and investment decisions in emerging forms of intelligence.

3 United Nations Office for the Coordination of Humanitarian Affairs. "Peer Review Framework for Predictive Analytics in Humanitarian Response (March 2020) - World." ReliefWeb, March 2020. https://reliefweb.int/report/world/peer-review-framework-predictive-analytics-humanitarian-response-march-2020.

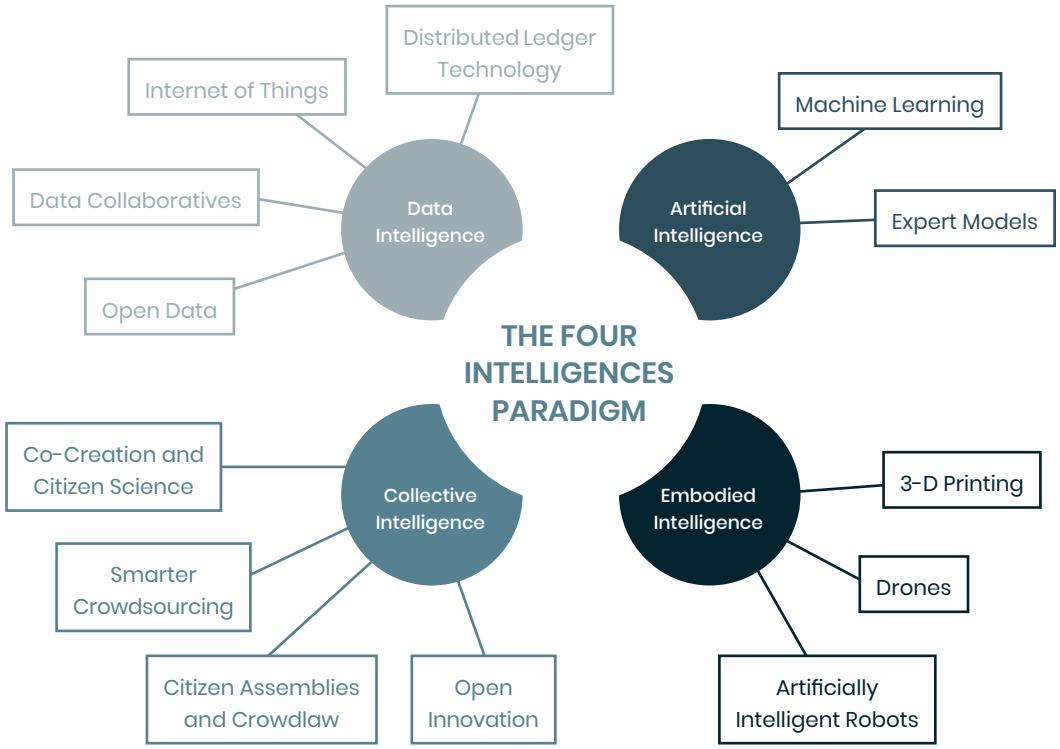
Paper Scope and Limitations

This is a position paper rather than a theoretical assessment or literature review. As such, its scope is limited to a discussion of new forms of intelligence derived from emerging uses of technology for the purpose of improving decision-making within development. It draws on dozens of use cases from across developing countries. Many, but not all, of the use cases we consider were deployed in French-speaking Africa, an important region for AFD's work. It does not seek to offer a comprehensive analysis of the sociotechnical implications of technology for development or a summation of all recent publications within the field. We also acknowledge that there are other cultural, social and economic uses of digital technology, including within development, that do not fit within the intelligence paradigm.

The concept of emerging exists on a spectrum in practice. Whether the use of a given technology is "emerging" is open to debate, and may vary considerably by context and use. Consequently, it could be argued that some of the cases described in this paper are not themselves emerging technologies, but practices that use mature technologies in novel ways for emerging purposes. For the sake of brevity, simplicity, and practical usefulness, we have chosen to include these emerging uses of technology within this paper.

Many development problems cannot be solved with technology alone. As later sections of this paper discuss, technological determinism—an over-reliance on technology to solve problems—and technological solutionism—the belief that all problems can be addressed through technology—can lead to harms such as project failure, disempowerment, the perpetuation or deepening of existing inequities, and environmental damage. Until they are regularly used and a practice develops around them, technologies can be slow to produce results and difficult to adapt to specific contexts. As a result, the benefits of technology must be carefully weighed against the risks, and chosen only when they are clearly more effective than non-technological solutions.

1.
Four Intelligences: Manifestations, and Illustrative Applications for Development



1.1 – Data Intelligence

Since the United Nations' high-level panel on the post-2015 development agenda called for a "data revolution for sustainable development," the importance of data for development has become well understood.[4] **Data intelligence (DI),** the first new kind of intelligence, encompasses the use of technologies and methodologies that allow for the analysis or visualization of "systemic information about the attributes of the entities contained in some well-defined aggregate" to support decision-making processes.[5] While data itself is not a technology but an input, large volumes of data can be collected, presented, or distributed to promote better decision-making. The following three forms of DI are important from a development perspective:

1. Open data, publicly available data that can be universally and readily accessed, used, and redistributed free of charge. Open data has seen extensive use across Africa, but, as the Web Foundation notes, progress remains defined by "a slowly iterative cycle between innovation, adoption, resistance, and realignment."[6]

Example: In 2015, Burkina Faso had a presidential election in the aftermath of an attempted coup and an uprising that ousted the country's president of 27 years. Observers considered the election to be potentially transformative, but worried about whether the outcome would be perceived as legitimate given a history of fraudulent elections.[7] The Election Commission and Burkina Open Data Initiative (also known as Bodi) sought to address these issues through transparent and rapid reporting of results. They subsequently developed

4 Bob Coll, et al, "We would like to hear from you: Launching online consultations for World Development Report 2021 – Data for Better Lives Concept Note," World Bank Blogs, May 6, 2020, https://blogs.worldbank.org/opendata/we-would-hear-you-launching-online-consultations-world-development-report-2021-data-better?cid=dec_tt_data_en_ext&cid=dec_tt_data_en_ext

5 Straaten, Jaap van der. "UNSD Review Omnibus. A Review of and Inputs to UNSD Civil Registration and Vital Statistics Standards and Methods Publications, 2010 to Date. Rotterdam, May 2020." A Review of and Inputs to UNSD Civil Registration and Vital Statistics Standards and Methods Publications, 2010. https://unstats.un.org/unsd/demographic-social/Standards-and-Methods/files/Handbooks/crvs/CRVS-IdM-E.pdf.

6 Web Foundation, "Africa Data Revolution Report 2018: Status and Emerging Impact of Open Data in Africa," http://webfoundation.org/docs/2019/03/Africa-data-revolution-report.pdf.

7 Hervé Taoko, and Dionne Searcey, "Burkina Faso Elects First New Leader in Decades," The New York Times, November 30, 2015, https://www.nytimes.com/2015/12/01/world/africa/burkina-faso-elects-1st-new-leader-in-decades.html.

a public, mobile-responsive web app through which poll workers could report election results in real time.[8] Though officials needed to brief local media and civil society about this work to ensure wide dissemination of results, the platform allowed organizers to compile and confirm vote tallies, and then to rapidly report those results to the public. Officials announced a winner a little over 24 hours after the polls closed, a result accepted by the losing candidates and observers.

2. Data collaboratives, a new form of collaboration in which different stakeholders, including the private sector and civil society, exchange their data to create public value. Though data collaboratives are subject to inflating interest and hype in that there are a growing number of examples across the world, analysis of their application for development remains somewhat limited.[9]

Examples: Senegal has a literacy rate of 51.9%, with large disparities by gender (64.8% for men and 39.8% for women).[10] Improving the literacy rate, especially for women, is a priority for the government, which has recently built many community schools and literacy centers.[11] In 2017, an international development company demonstrated how private-sector resources could supplement existing administrative data in helping the government determine where to invest. Using call detail records "based on more than 9 million unique mobile phone numbers" from the telecom Orange/Sonatel, the researchers estimated the regions of Senegal where illiteracy was most prevalent.[12] The researchers subsequently published a paper that shared results and demonstrated how such methods can derive value for development through the use of telecommunications data.

Second, this work led to the creation of OPAL, a not-for-profit project supported by AFD, the Data-Pop Alliance, Imperial College London, MIT Media Lab, Orange, and the World Economic Forum to securely and ethically collect private-sector data, analyze it, and provide insights on various development issues for government or humanitarian organizations. OPAL's platform pseudo-anonymizes selected datasets from company servers. Researchers can then use OPAL's algorithms to analyze the data in OPAL's secure local database. OPAL had two pilot projects with the governments of Senegal and Colombia, using data from Orange Sonatel and Telefonica Colombia to address development problems.[13]

3. Internet of Things (IoT), which creates insight through data derived from digital devices and sensors with embedded processors. IoT applications are commonly used by the utility and energy sector across Europe and North America.[14] They are also increasingly used by consumers as in-home personal assistants and home automation systems, among many other use cases. However, the cost of deploying infrastructure (e.g. 5G telecommunications) and providing training needed for IoT can be significant in regions with significant poverty or other resource constraints.[15] Consequently, most implementations are nascent, limited to small-scale pilots, or require multi-sector buy-in.

Example: Access to water is essential in any environment but, across many parts of sub-Saharan Africa, this access is limited by non-functioning infrastructure. In Rwanda, 30 percent of rural communities lack water points.[16] International development practitioners, governments, and other stakeholders have sought to repair these structures, but actors often do not know where they are. Consequently, a company developed remote sensors that monitor water pump performance and flow and

8 Anna Scott. "Burkina Faso's open elections," The ODI, 2016, https://theodi.org/project/case-study-burkina-fasos-open-elections/.
9 Data Collaboratives. "Data Collaboratives Explorer," 2018. http://datacollaboratives.org/explorer.html.
10 "Senegal," UNESCO UIS, April 12, 2017, http://uis.unesco.org/en/country/sn.
11 Timo Schmid et al. "Constructing socio-demographic indicators for National Statistical Institutes using mobile phone data: Estimating literacy rates in Senegal," EconStor, 2016, http://hdl.handle.net/10419/130591.
12 "Knuper Data Upcycling in Senegal," The GovLab, accessed September 14, 2020, https://datacollaboratives.org/cases/knuper-data-upcycling-in-senegal.html.
13 "About OPAL," OPAL Project, accessed September 14, 2020, https://www.opalproject.org/about-opal.
14 Research and Markets. "Global Electrical SCADA Market Report 2020: Developments in IoT Technology and Cloud Computing Has Increased Growth." PR Newswire, October 22, 2020. https://www.prnewswire.com/news-releases/global-electrical-scada-market-report-2020-developments-in-iot-technology-and-cloud-computing-has-increased-growth-301157960.html.
15 Ndubuaku, Maryleen, and D. Okereafor. "Internet of Things for Africa: Challenges and Opportunities," 2015. https://doi.org/10.13140/RG.2.1.2532.6162.
16 Elizabeth L. Kleemeier, "Private Operators and Rural Water Supplies: A Desk Review of Experience," Open Knowledge Repository, World Bank, Washington, SC, November 1 2010, https://openknowledge.worldbank.org/handle/10986/17248.

notify technicians, NGO program managers, and others if a pump fails or requires maintenance.[17] The company, supported by USAID and others, installed these sensors in over 200 communities across Rwanda, resulting in more reliable operation and a 35% reduction in broken pumps at any given time. The sensors cost about USD 100 upfront with recurring costs for data transfer. The pumps need replacement after 12–18 months of use.[18]

Distributed Ledger Technologies

Distributed Ledger Technologies (DLT), including blockchain, can supplement new forms of intelligence and amplify their positive impact. DLT uses advanced cryptography to store blocks of data (or ledgers) across a network of computers or nodes. They seek to solve problems of information asymmetries affecting transparency, accountability and efficiency during a transaction between two or more parties.[19]

DLT applications can support development objectives by "track and trace" tangible and intangible objects, verify identity through the use of immutable identifiers, or ensure the automatic execution of certain tasks once pre-defined conditions are met ("smart contracts").

While they may be useful in some capacities, DLT remains "under development" and are too cross-cutting to be grouped in with any of the four types of intelligence. Development practitioners can best consider them as an enabler of other technologies discussed in this paper, though they should be aware that the disruptive nature of DLT can spark substantial resistance to its use among local actors whose interests they might threaten. Moreover, large-scale uses of particular DLTs result in a substantial carbon footprint and potential energy security issues.[20] Practitioners should also be aware that for all the hype surrounding DLT, there are still very few unqualified successes and even fewer large-scale deployments, even in highly developed economies.[21]

1.2 – Artificial Intelligence

The second type of intelligence that can aid development decision-makers is **artificial intelligence (AI).** The original goal of AI was to design algorithms that work in a similar way as the human mind. However, current approaches are typically only able to solve rather specific tasks.[22] Still, these methods are expected to yield significant changes in various fields, including development. Well-developed and emerging AI methods can be classified in two subcategories: machine learning and expert models.

1. Machine learning, which comprises algorithms that can learn from and improve their performance through examples, data, and experience, is subject to inflating interest and hype.[23] Though some recent media coverage and analysis shows skepticism about its usefulness, machine learning is

17 "SweetSense Pioneering Internet of Things at Scale for Water Resource Management in East Africa," SweetSense Inc., September 14, 2017, http://www.sweetsensors.com/library/sweetsense_nsf_usaid_release/.
18 John Garrity, "Harnessing the Internet of Things for Global Development," SSRN, April 2, 2015, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2588129.
19 Stefaan G. Verhulst, "Information Asymmetries, Blockchain Technologies, and Social Change," Medium, Medium, July 24, 2018, https://medium.com/@sverhulst/information-asymmetries-blockchain-technologies-and-social-change-148459b5ab1a.
20 Christian Stoll, Lena Klaaßen, and Ulrich Gallersdörfer, "The Carbon Footprint of Bitcoin," *Joule* 3, no. 7 (2019): 1647–61, https://doi.org/10.1016/j.joule.2019.05.012.
21 Jesse Frederik, "Blockchain, the Amazing Solution for Almost Nothing," The Correspondent, August 21, 2020, https://thecorrespondent.com/655/blockchain-the-amazing-solution-for-almost-nothing/86714927310-8f431cae?pk_campaign=sneak-peek.
22 J. Schoonhoven et al, "Beyond the hype: A guide to understanding and successfully implementing artificial intelligence within your business," IBM White Paper, October 2018. https://www.ibm.com/downloads/cas/8ZDXNKQ4
23 C. M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2006.

an important part of various development projects and analyses.[24]

Example: In East Africa, poor road conditions are a hazard for drivers and a drag on transportation speed, which inhibits economic growth. The World Bank estimates improving a 100 km section of a 1,000 km road in East Africa from "poor" condition to "good" would produce between a 20 and 65 time return on investment depending on traffic.[25] Researchers with the University of Nottingham and the United Kingdom's Department for International Development conducted an automated road condition survey project in Tanzania that labelled the quality of unpaved roads on a seven-point scale using satellite images and deep learning techniques. The machine learning algorithm managed to assign images to road conditions with 73% accuracy, a relative success. The algorithm flagged images for which human judgement was required. The major barrier to achieving even higher accuracy was image quality (blurring, over-exposure), not the functioning of the algorithm.[26]

2. Expert models, which refers to an artificial system that attempts to mimic the decision-making of a human expert by following a set of predefined rules.[27] Expert systems, created in the 1970s, were among the first successful examples of AI algorithms. While general interest in expert systems is deflating, rule-based algorithms, which follow the same basic architecture, are established in many fields relevant to development. Thus, expert systems can be viewed as a mature use of technology.[28]

Example: In 2014, a UN Department of Economic and Social Affairs survey of Bangladesh gave the country an e-government development index score of 0.28 (84th overall). This figure was low both in terms of the world average (0.47) and the regional average (0.50).[29] That same year, a group of researchers investigated the utility of a belief-rule-based expert system to help the government assess how well e-governance is received by the population and where its benefits and weaknesses are felt. The system has shown to be 25% more accurate and reliable than other methods, identifying problems with e-government projects that need to be addressed or finding and comparing different scenarios.[30] However, it needs either expert knowledge or historical data to operate.

1.3 – Collective Intelligence

Collective Intelligence (CI) projects use networked technologies to tap into the ideas, perceptions, and expertise of groups of people, whether those people are beneficiaries or domain experts.[31] Similar to in-person mechanisms for tapping into collective wisdom, technology-enabled CI projects often aim to support innovation while increasing the democratic nature of problem-solving efforts. Unlike the other forms of intelligence discussed in this paper, CI projects rely on the emerging diffusion of relatively simple digital devices (e.g. smartphones) that can connect to centrally managed platforms. CI can also be an important enabler of other intelligences by generating new data or activating distributed capacity. Its forms include:

1. Participatory Co-creation is the use of networked technology tools that allow individuals to collaborate and jointly develop new knowledge. This work is closely related to other means for mobilizing the capacity of a distributed crowd such as citizen science projects[32] and crowdfunding. Participatory mapping is a common form of participatory co-creation enabled by mobile technologies. The

24 Kartik Hosanagar and Apoorv Saxena, "The first wave of corporate AI is doomed to fail", Harvard Business Review, 2017. https://hbr.org/2017/04/the-first-wave-of-corporate-ai-is-doomed-to-fail; Evgeny Chershnev, "Why the AI euphoria is doomed to fail", VentureBeat, 2016. https://venturebeat.com/2016/09/17/why-the-a-i-euphoria-is-doomed-to-fail/.

25 Supee Teravaninthorn and Gaël Raballand, "Transport Prices and Costs in Africa : A Review of the International Corridors," Open Knowledge Repository (Washington, DC : World Bank, January 1, 1970), https://openknowledge.worldbank.org/handle/10986/6610.

26 https://indd.adobe.com/view/93905665-ef29-4d41-92e2-c49eb4507b3a

27 S. Russel and P. Norvig, "Artificial Intelligence: A Modern Approach", Prentice Hall, 2002

28 David Haskin, "Expert systems' paying off for some", Datamation, 2003.
https://www.datamation.com/netsys/article.php/1570851/Years-After-Hype-Expert-Systems-Paying-Off-For-Some.htm

29 "UN E-Government Knowledgebase - Bangladesh," United Nations (United Nations), accessed September 14, 2020, https://publicadministration.un.org/egovkb/en-us/Data/Country-Information/id/14-Bangladesh/dataYear/2014

30 Mohammad Shahadat Hossain et al. "Belief-Rule-Based Expert Systems for Evaluation of E-Government: A Case Study," Expert Systems, 2015. https://arxiv.org/abs/1403.5618.

31 Noveck, B. S., R. Harvey, and A. Dinesh. «The open policymaking playbook.» New York: The Governance Lab at New York University. Retrieved June 19 (2017): 2019. https://www.thegovlab.org/static/files/publications/openpolicymaking-april29.pdf.

32 Steffen Fritz, et al. "Citizen science and the United Nations Sustainable Development Goals." *Nature Sustainability*, October 9, 2019, https://www.nature.com/articles/s41893-019-0390-3.

OpenStreetMap platform is a notable tool supporting such projects, including for instance, a flood risk mapping project in Uganda[33] and an AFD-funded effort to improve scientific impact evaluations through participatory mapping in Tunisia.[34] Co-creation and citizen science has been maturing through wide-ranging experimentation, fact-finding, and iteration but would benefit from additional research into and evidence regarding what types of platforms or approaches are fit-for-purpose in different development contexts.

Example: The Prey Lang forest in Northern Cambodia suffers from illegal land use and logging, which negatively impact the 200,000 people and many endangered plants and animals that live there. Countrywide, Cambodia has lost 23% of its tree cover since 2000.[35] Anti-Deforestation App Cambodia is a mobile and web app that enables residents to collect evidence of illegal land use and logging in the Prey Lang forest. The app, which aims to mitigate the impact of illegal activity, was developed by a consortium of local activists, missionary organizations, NGOs, human rights groups, and universities. Users can submit text reports, photos, or audio, and the system automatically geotagged all submissions. Information is uploaded to a central database through a Dropbox API that informs and targets enforcement and patrolling activities.[36] However, the system depends on the ability of rangers to patrol and capture geolocation information in a dense forest environment. Rangers can face connectivity and geolocation accuracy challenges.

A similar initiative was launched in Côte d'Ivoire to slow deforestation in the Mé region. The GeoPoppy is an open-source mobile tablet application, also supported by AFD, that allows users to track, map, and monitor endangered areas, including the Mabi-Yaya forests.[37]

2. (Smarter) Crowdsourcing uses technology platforms to solicit ideas from a global body of experts to develop actionable responses to well-defined public problems or challenges.[38] Smarter crowdsourcing is premised on the idea that while some problems are well-suited for open-call crowdsourcing, with participation open to all interested parties, other problems are better addressed through the targeted engagement of individuals with desired knowledge, experience, or expertise. It remains a nascent use of technology in development contexts, with relatively few larger-scale applications.

Example: Gender-based violence is a major problem in Kenya, with 45 percent of women and girls between the ages of 15 and 49 having experienced physical violence and 14% having experienced sexual violence. Victims often do not receive adequate care or see their assailants charged.[39] MediCapt is a secure digital platform, developed by Physicians for Human Rights, that enables doctors to capture forensic medical evidence of gender-based violence in Kenya and the Democratic Republic of Congo. Doctors use the system to share "forensic photography of survivors' injuries" and transmit relevant data to authorities.[40] The system is an example of precisely targeted smarter crowdsourcing to obtain highly sensitive information that is useful to public authorities.[41] The risks of data breach or unauthorized access necessitate significant investment in data protection and cybersecurity technology and expertise.

3. (Digital) Citizen Assemblies: the use of networked technologies and platforms (e.g. collaborative online document drafting systems, video conferencing and synchronous communication platforms) that enable public deliberation and policy co-creation, or "Crowdlaw."[42] These techno-

33 Humanitarian OpenStreetMap Team"Mapping and Surveying of the Nakamiro Channel Area in Kampala." https://www.hotosm.org/projects/mapping-and-surveying-of-the-nakamiro-channel-area-in-kampala/

34 "Strengthening Scientific Impact Evaluations through Mapping: Case Study in Tunisia with the Evaluation of PRIQH2," Cartong, August 21, 2019, https://www.cartong.org/news/strengthening-impact-evaluations-through-mapping-case-tunisia

35 "Cambodia Deforestation Rates & Statistics: GFW," Global Forest Watch, accessed September 14, 2020, https://www.globalforestwatch.org/dashboards/country/KHM/?category=summary.

36 "Anti Deforestation Mobile & Web App: Web Essentials," Web Essentials, accessed September 14, 2020, https://www.web-essentials.co/success-stories/web-application/app-fighting-deforestation-prey-lang-cambodia.html.

37 "Côte D'Ivoire: GeoPoppy Challenges Deforestation," AFD, May 1, 2018, https://www.afd.fr/en/actualites/grand-angle/cote-divoire-geopoppy-challenges-deforestation.

38 "Smarter Crowdsourcing," Smarter Crowdsourcing (The GovLab), accessed September 14, 2020, https://smartercrowdsourcing.org//about.html.

39 Agnes Odhiambo, "Tackling Kenya's Domestic Violence Amid COVID-19 Crisis," Human Rights Watch, April 8, 2020, https://www.hrw.org/news/2020/04/08/tackling-kenyas-domestic-violence-amid-covid-19-crisis.

40 "MediCapt," GIE, July 13, 2020, https://www.globalinnovationexchange.org/innovation/medicapt.

41 "MediCapt," Physicians for Human Rights, January 15, 2020, https://phr.org/issues/sexual-violence/medicapt-innovation-2/.

42 See crowd.law

logy-enabled efforts are informed by significant global experience in the use of similar deliberative processes conducted in person without technological mediation, and are subject to inflating interest and hype. Researchers are beginning to capture evidence and insights from emerging practice, but experimentation remains limited in development contexts.

Example: Since 2016, Uganda has prioritized investments in strategic infrastructure development, including nearly USD 4 billion invested in transportation infrastructure. Two years later in 2018, the World Bank found these projects have "no value for taxpayer money."[43] The Infrastructure Transparency Initiative (CoST), consequently, is a global framework for civic participation that was deployed in Uganda to connect policymakers directly to citizens at the traditional community level called "barazas." Through community events, people in the barazas can communicate their infrastructural needs to officials. For example, officials in Wakiso, Uganda held a CoST initiative where they explained their plan to build a major road to the residents. In this event, residents expressed their concerns and asked questions concerning this road development.[44]

4. Open Innovation: the use of contests, challenges, and incentive prizes to initiate competition within a crowd and shift the locus of innovation from institutions to public channels.[45] This approach has been implemented in various forms across regions and sectors. The open innovation evidence base is substantial and evolving.
Example: Drone imagery can inform an array of development activities and decision-making—from tracking deforestation to coordinating disaster response. However, manual analysis of drone imagery is burdensome. Imagery from a 20-minute flight takes around 13 hours to analyze.[46] To alleviate this burden, a technology nonprofit has organized three Open AI Challenges, open innovation efforts aimed at using CI to develop AI tools for analyzing drone footage.[47] Focused on countries such as Tanzania, the organization engages with Africa-based innovators to identify new ways to support decision-making, make use of drone footage, or improve how others do business.[48]

1.4 – Embodied Intelligence

Embodied intelligence (EI) is the use of artificial intelligence in the physical world for the purposes of computer automation, deployment, and planning. It is the manifestation of technological processes through real-world, tangible artefacts. It is based on the concept of embodied cognition: that intelligence comes not only from the brain but from the relationship between the brain and the body.[49] Embodied intelligence can be used in development contexts where human operators cannot be physically present. For example, it can include automating time-intensive or risky processes and increasing the reach or scope of development activities, such as resource provision. The most widely recognized types of embodied intelligence are:

1. Robots are multifunctional, reprogrammable machines that can perform a variety of tasks. Here, we focus in particular on robotic systems that are controlled by AI software to make decisions and move around a physical space. This technology remains nascent as very few development projects with fully automated processes exist on a large scale or otherwise.
Example: An estimated nine million Kenyans remain unconnected to the internet.[50] Google's Project

43 Ronald Mugabe, "73.5% Of Ugandans Not Satisfied with the Quality of Infrastructure Projects," New Vision, July 10, 2019, https://www.newvision.co.ug/news/1503296/735-ugandans-satisfied-quality-infrastructure-projects.

44 "Amplifying Resident Voices for Better Infrastructure in Uganda," Observatory of Public Sector Innovation, June 3, 2020, https://oecd-opsi.org/innovations/amplifying-resident-voices-for-better-infrastructure-in-uganda/.

45 Stefaan G. Verhulst and Andrew Young, "Governing through Prizes and Challenges," Medium, January 27, 2015, https://medium.com/@sverhulst/governing-through-prizes-and-challenges-677f3ef861d1

46 "Announcing the Winners of the Open AI Tanzania Challenge," WeRobotics Blog, December 6, 2018, https://blog.werobotics.org/2018/12/06/announcing-the-winners-of-the-open-ai-tanzania-challenge/.

47 Aleks Berditchevskaia and Peter Baeck, "The Future of minds and machines: How artificial intelligence can enhance collective intelligence," Nesta, March 2020, http://www.nesta.org.uk/report/future-minds-and-machines.

48 "Announcing the Winners of the Open AI Tanzania Challenge," WeRobotics Blog, December 6, 2018, https://blog.werobotics.org/2018/12/06/announcing-the-winners-of-the-open-ai-tanzania-challenge/.

49 Samuel McNerney, "A Brief Guide to Embodied Cognition: Why You Are Not Your Brain," Scientific American Blog Network (Scientific American, November 4, 2011), https://blogs.scientificamerican.com/guest-blog/a-brief-guide-to-embodied-cognition-why-you-are-not-your-brain/.

50 Communications Authority of Kenya. "Third Quarter Sector Statistics Report for the Financial Year 2019/2020 (January - March 2020)." Nairobi, Kenya, July 2020. https://ca.go.ke/wp-content/uploads/2020/07/Sector-Statistics-Report-Q3-2019-2020-.pdf#page=18.

Loon, in partnership with Telkom Kenya, launched a fleet of balloons with AI-enabled robotics that will deliver network connectivity in remote locations of the country, delivering 4G LTE service across central and western provinces.[51] Connectivity can serve many purposes, including emergency management and education. According to Austin Mwakalinga, head teacher at a primary school in UNICEF's drone corridor in Malawi, mobile network connectivity is "[their] greatest need in this area."[52] While there is significant potential value for development arising from expanding connectivity, the on-the-ground impacts of the initiative are still emerging.

2. Unmanned aerial vehicles (UAVs, also known as "drones") are aircrafts without a human pilot on board. UAVs are a specific example of robots. However, since there is an increasing number of projects using UAVs, we address them separately. UAVs are often used when it may be less safe or convenient for an aircraft to be piloted. They can be fully or partially autonomous, though they are most often controlled by a remote pilot.[53] These devices are subject to inflating interest and hype, with a growing number of UAV-related programs tested across sub-Saharan Africa. One barrier to take up is regulatory, as the use of UAVs is generally controlled by the national aviation authority of the country.

Example: Agriculture employs 70% of Uganda's workforce but productivity is very low, growing at a rate of 2% per annum compared to 3–5% for other East African countries.[54] With support from the Bill & Melinda Gates Foundation, a technology nonprofit launched an initiative with farmers in Uganda to use drones to help them better monitor and grow crops. Initial findings from the work found that farmers gained an average of USD 2,150 in incremental annual profits while pesticide application decreased by 60 percent.[55]

3. 3-D printing, a form of additive manufacturing, works by depositing layers of material one at a time until they form a fully realized three-dimensional object. Similar to how a regular printer only deposits ink in certain locations based on the document it reads, a 3-D printer only adds a layer of material based on a file produced from 3-D modeling software. While 3-D printing itself can hardly be classified as an "intelligent" technology, it can be seen as an enabler for other types of intelligence. 3-D printing allows for rapid and cheap prototyping. That way, it can enable collective intelligence. Moreover, if, for instance, an AI-powered mobile robot is 3-D printed, it is fast and cheap to repair. This greatly simplifies data generation through experiments, as it is not as critical if the robot is damaged during experiments, and scalability[56]. 3-D printing is nascent in that it has most often been applied in small-scale projects, and it is unclear how easily it could be scaled to a country level.

Example: At the beginning of the COVID-19 crisis, Nairobi-based company Ultra Red Technologies and a group of other Kenyan 3-D printing companies used 3-D models from Swedish company 3DVerkstan to print plastic face shields for healthcare workers during the COVID-19 crisis.[57] These efforts have filled a gap in the plastic production market, allowing for new forms of quick and affordable aid. Though long-term benefits of this work remains to be seen, the company is producing up to 500 face shields per day to support public health authorities.[58]

51 Bethlehem Feleke, "Google Launches Balloon-Powered Internet Service in Kenya," CNN (Cable News Network, July 8, 2020), https://www.cnn.com/2020/07/08/africa/google-kenya-balloons/index.html.

52 UNICEF Malawi, "Drones: Remote School Highlights Challenges of Rural Education," Medium (Medium, July 18, 2017), https://medium.com/@unicef_malawi/drones-remote-school-highlights-the-challenges-of-rural-education-38aed2c84015.

53 "Unmanned Aerial Vehicles," RAND Corporation, accessed September 14, 2020, https://www.rand.org/topics/unmanned-aerial-vehicles.html.

54 "Closing the potential-performance divide in Ugandan Agriculture," World Bank, Washington, DC, 2018, http://documents.worldbank.org/curated/en/996921529090717586/Closing-the-potential-performance-divide-in-Ugandan-agriculture.

55 TechnoServe, "Can Drones Change Africa's Agricultural Future?," TechnoServe (TechnoServe, July 22, 2020), https://www.technoserve.org/blog/can-drones-change-africas-agricultural-future-2/.

56 https://arxiv.org/pdf/1910.00093.pdf

57 Neha Wadekar, "Kenya's 3D Printing Community Is Making Covid-19 Equipment to Fill a Deficit as Caseloads Rise," Quartz Africa (Quartz, April 16, 2020), https://qz.com/africa/1838608/kenyas-3d-printing-community-making-covid-19-equipment/.

58 News Wires, "'We Can Get It Done Here': African Tech Tackles Coronavirus Locally," France 24 (France 24, May 19, 2020), https://www.france24.com/en/20200519-we-can-get-it-done-here-african-tech-tackles-coronavirus-locally.

2.
The Potential Upside: Value and Benefits

Emerging uses of technology can disrupt or sustain legacy systems as well as enhance or complement existing processes. These effects can be useful generally, but, often, development practitioners need a tool to help them improve processes in a specific way. They need technology to improve how they operate in pursuit of any of the 17 SDGs.

Consequently, we sought to identify specific outputs of emerging uses of technology useful to development practitioners. Our analysis of real-world examples and literature led us to conclude the responsible use of technology for development lends itself best to seven types of value. Some uses of technology are better suited for some values than others. Technologies in one type of intelligence can be combined with technologies in another type to address gaps or improve value.

In the section below, we provide explanations as to what we mean by each of these values and use two illustrative examples to illustrate their real-world impact. These examples are not meant to be comprehensive or representative but to show how each intelligence type can produce value. We argue emerging uses of technology can facilitate:

1. Enhanced knowledge and (real-time) situational awareness. Emerging uses of technology can fill gaps in information, identify patterns and relationships, and help practitioners foresee risks and opportunities. DI and AI can be useful in achieving this value by helping practitioners identify patterns in available data. EI can add value by increasing the amount of available data even further (e.g. through the use of UAVs for plant monitoring as described in Sec. II-D). Further examples include:

- ***DI:*** Nigeria's National Oil Spill Detection and Response Agency, one of the country's environmental regulators, maintains an online Oil Spill Monitor. The site acts as a public database and visualization of previously inaccessible or siloed information on all detected oil spills in Nigeria, aiming to show the public the current state of compliance—which oil companies are meeting their legal obligations—and the scale of illegal refining in the Niger Delta.[59]
- ***AI:*** The child-growth monitor, developed by the German nonprofit Welthungerhilfe, aims at detecting undernourished children. As malnutrition can be difficult to detect for the human eye, the child-growth monitor leverages machine learning algorithms. In particular, children are scanned with a smartphone, and the app then uploads the data to a cloud where it is analyzed with machine learning algorithms. These algorithms can reliably detect malnutrition and further improve their performance as more data is collected. Future versions aim to process the data locally on the smartphone, which could improve privacy protections and be useful in developing countries and contexts where internet access is limited.[60]

2. Improved forms of assessment, prediction, and experimentation. Emerging uses of technology can improve impact assessment through insight into causes of success or failure and enable virtual modelling to identify optimal interventions. This value benefits from DI methods that provide more data for assessment and AI algorithms that can analyze this data. For example:

- ***DI:*** The Ghana Statistical Services is working with Vodafone Ghana, the telecommunications company, and the Flowminder Foundation, the Stockholm-based nonprofit, to improve the national government's COVID-19 response. Using anonymised and aggregated mobile phone data provided by Vodafone, Ghana Statistical Services and Flowminder will try to determine the impact mobility restrictions instituted by the government have on a district, regional, and national level. These analyses will inform subsequent government action to combat COVID-19 spread.[61]

Additionally, prior to the implementation of development projects, public development banks often conduct detailed environmental impact assessments to inform their investment decision-making. These reports often yield novel and useful data on the current state of biodiversity and how that is likely to change if certain conditions change. Despite their broad potential value, these reports generally are not made publicly accessible. The Data4Nature initiative aims to source biodiversity data drawn from these environmental impact

59 "Reporting - Submit Oil Spill Emergency Alerts," Nigerian Oil Spill Monitor, Accessed September 14, 2020, https://oilspillmonitor.ng/.
60 Markus Matiaschek, "Child Growth Monitor - Quick, Accurate Data on Malnutrition," Child Growth Monitor - Quick, accurate data on malnutrition (Welthungerhilfe), accessed September 14, 2020, https://childgrowthmonitor.org/.
61 "Preliminary Mobility Analysis to Support the Gov't of Ghana in Responding to the COVID-19 Outbreak," Ghana Statistical Services, April 3, 2020, https://statsghana.gov.gh/headlines.php?slidelocks=MTI0MDM5Njc1Ny42OTU1%2Fheadlines%2Fn1r7pr567p.

studies conducted by public development banks in various contexts. This data is compiled and made accessible in the Global Biodiversity Information (GBIF). The GBIF contains over 1.6 billion species occurrence records of fauna and flora around the world. This previously inaccessible and/or distributed information is now accessible to policymakers, researchers, and other actors positioned to use it to inform their work.[62]

- ***AI:*** The Red Cross used AI technologies to fuse various information sources (e.g. hydrometeorological and humanitarian data) to predict overspills of the Nagbeto dam in Togo. The better forecasts decreased the impact of the overspills and corresponding floods and helped the red cross in Togo to prepare vulnerable communities.[63]

3. Greater legitimacy and effectiveness of decisions. Emerging uses of technology can broaden participation, leading to more legitimate and agile decision-making, and improve collaboration with hard-to-reach communities and the expertise they possess. They can also give leaders evidence on which to base and justify their decision-making. AI, especially in the form of natural language processing, can add value by, for instance, providing a means for illiterate people to participate in digital engagement efforts.[64] CI, meanwhile, expands the circle of participation in decision-making, providing avenues for greater public representation. For example:

- **DI:** The telecom provider Digicel Haiti and researchers at Karolinska Institutet, Sweden, and Columbia University deployed the predictive capacities of data in their work in Haiti following the 2010 cholera outbreak. Using anonymized data from two million mobile phones, the participants monitored population movements from two days before the 2010 earthquake until 158 days afterwards. Patterns from these movements helped humanitarian responders predict where aid delivery would be most needed. Information on the project was published in PLOS Medicine.[65]

- **CI:** Supporting legitimate and effective institutional decision-making can be essential in development contexts. TransGov is a Ghanian platform helping citizens monitor local development projects. The mobile platform provides users with a curated list of open infrastructure initiatives in their community and the ability to provide feedback or commentary on those efforts. Users can also use the platform to report and track infrastructure-related complaints such as burst pipelines. The project seeks to increase the legitimacy of public infrastructure decision-making and to provide residents with the ability to act as a public check and accountability mechanism in their communities.[66]

4. Expanded capabilities and skills. Emerging uses of technology offer ways to increase individual skills and community capabilities through peer-to-peer knowledge sharing and remote learning. The ability of AI to help deliver this value especially stems from its capacity to learn from data and experience, allowing those algorithms to adapt the learning curriculum based on the skills and improvements of the person using the learning tool. CI can expand capabilities by giving institutions access to outside skills and expertise they might otherwise be lacking. For example:

- ***AI:*** M-Shule, launched in Kenya in 2016, is a mobile platform that delivers lessons based on the national curriculum to each student via SMS. It adapts to children based on their skills and abilities using AI technology.[67] The project has successfully completed a pilot phase with 400 students across 15 schools and is envisioned to now take up and

62 Agence française de développement, and Global Biodiversity Information Facility. "Data 4 Nature." Agence française de développement, August 27, 2020.

63 The Climate Centre, "Red Cross Shares in Global Innovation Award at World Government Summit in UAE," Red Cross Red Crescent Climate Centre, February 15, 2017, https://www.climatecentre.org/news/833/red-cross-shares-in-global-innovation-award-at-world-government-summit-in-uae.

64 M. Plauche et al, "Speech Recognition for Illiterate Access to Information and Technology," International Conference on Information and Communication Technologies and Development, 2006.

65 "Digicel Telecom, Karolinska, and Columbia University Partnership," The GovLab, Accessed September 14, 2020, https://datacollaboratives.org/cases/digicel-telecom-karolinska-and-columbia-university-partnership.html.

66 "Social Auditing," Crowdlaw for Congress - The GovLab, accessed September 14, 2020, https://congress.crowd.law/case-social-auditing.html.

67 Francesc Pedro, Miguel Subosa, Axel Rivas, and Paula Valverde. "Artificial intelligence in education: Challenges and opportunities for sustainable development", accessed October 07, 2020. https://unesdoc.unesco.org/ark:/48223/pf0000366994

reach up to 1 million students in East Africa in the near future. The platform was developed by a startup, also called M-Shule.[68]

- ***CI:*** Responding to the limited availability of ambulances in Tanzania, the Vodafone Foundation built an emergency response system that crowdsources medical transportation to the community. This system was built to help pregnant women in the Sengerama and Shinyaga get the proper medical treatment in emergencies. Users can call a 24-hour line when in need of medical attention. Dispatchers will ask a series of questions to determine the level of urgency the user needs and connect the user with a community driver or an ambulance. Once the trip is completed, the driver is paid by Vodafone with mobile money. A year after the system was launched in 2016, the system helped 2,523 women who needed pregnancy emergencies. Vodafone reported an 80 percent decrease in maternal fatalities in the districts following implementation.[69]

5. New forms of service provision, aid, and economic opportunities. New forms of intelligence, including especially AI, offer various possibilities for offering new services, such as through automating and simplifying processes. EI has similar potential as it brings those algorithms into the real world. Further, 3D printing allows for cheap and fast production. For example:

- ***AI:*** The startup Apollo Agriculture in Kenya uses satellite data to train machine learning models that automatically build digital processes for, e.g., customer acquisition or collecting payments. Through these digital processes, Apollo then makes its decisions about lending and credit provision.[70]

- ***EI:*** In Lebanon, the file-sharing platform MyMiniFactory worked with Oxfam to develop a 3-D printing solution that would allow Syrian refugees to sanitize their hands more.[71] A series of custom models were printed in the field and tested, ultimately helping to improve public health in refugee camps. The effort was completely crowdsourced, allowing 3-D modelers from around the world to submit their designs for consideration. Ultimately, five designs were selected and tested in the field.[72]

6. Improved efficiency and automation. Emerging uses of technology can increase the agility and efficiency of interventions through automation, freeing human operators for more complex tasks. AI and EI are both a natural fit for this value, the former taking over time consuming tasks (e.g., analyzing large amounts of data) and the latter repetitive or physically demanding tasks. For example:

- ***AI:*** Routine tasks are often characterized by repeating patterns. An example for such a usage of AI technology is the startup Zenvus. Zenvus uses machine learning techniques to fuse data from proprietary electronics sensors (e.g., moisture, nutrients, pH).[73] Farmers collect data with typical electronic sensors and send them to a cloud via GSM or WiFi. Zenvus' machine learning algorithms analyze these data and recommend actions to maximize yield. Showing how multiple forms of intelligence can combine, the system also makes use of special IoT cameras to detect drought stress, pest, and diseases.

- ***EI:*** While AI can recommend actions, EI can actually take actions in the real world. This provides additional potential in terms of increasing automation. In Rwanda, the Zipline Initiative, a national drone delivery service, used autonomous drones for medical product delivery. Based on the success of this effort, the government partnered with the World Economic Forum in 2018 to co-design a policy framework for drone regulation.[74] The framework paves the way for further autonomous deployments.

7. Increased social and political capital and networks. Emerging uses of technology such as peer-to-peer platforms can expand opportunities for horizontal knowledge transfer, skill-building,

68 Gabriella Mulligan, "The startup bringing AI-powered SMS-based learning to Kenya", Disrupt Africa, accessed October 07, 2020. https://disrupt-africa.com/2018/03/the-startup-bringing-ai-powered-sms-based-learning-to-kenya/

69 Matt Petronzio, "How an 'Uber for Pregnant Women' Is Saving Lives in Tanzania," Mashable, April 15, 2017, https://mashable.com/2017/04/15/vodafone-maternal-health-uber-ambulance/.

70 "Apollo Agriculture," Apollo Agriculture, accessed September 14, 2020, https://www.apolloagriculture.com/.

71 Srinivas Saripalle et al., "3D Printing for Disaster Preparedness: Making Life-Saving Supplies on-Site, on-Demand, on-Time," *2016 IEEE Global Humanitarian Technology Conference (GHTC)*, 2016, pp. 205-208, https://doi.org/10.1109/ghtc.2016.7857281.

72 MyMiniFactory. "Oxfam," 2014. https://www.myminifactory.com/category/oxfam.

73 Ekekwe, Ndubuisi. "Zenvus – Intelligent Solutions for Farms." Startup Info (blog). Accessed October 7, 2020. https://startup.info/zenvus/.

74 "Zipline," 2020. https://flyzipline.com/.

and information sharing. This value can be best achieved through CI, which, by its nature, seeks to connect groups of people in pursuit of a common goal. For example:

- ***CI:*** Participants in collective intelligence projects often highlight the networking value of their engagement. Interactive community mappers in Jamaica, for instance, indicated that the development of new skills and connections with peers were key benefits of their work.[75] The participants co-created tourism maps aimed at encouraging visitors to the island to travel outside of resorts or other well-trafficked areas, and to expand the economic value of tourism. This network building not only provided participants with a new peer group and skills, but also yielded an experienced network of mappers that the project organizer could engage for future opportunities.

Similarly, Wefarm is an SMS-based peer-to-peer platform for smallholder farmers to pose questions and share information to enable peer learning. The platform has been deployed in Kenya, Uganda, and Tanzania, and works in English and the African regional languages of Kiswahili, Luganda, and Runyankore. A machine learning algorithm supports peer learning by matching questions submitted by farmers to the user deemed most capable of providing a useful response.[76]

75 Andrew Young and Stefaan Verhulst, "Jamaica's Interactive Community Mapping," Open Data's Impact - The GovLab, 2017, http://odimpact.org/case-jamaicas-interactive-community-mapping.html.

76 "WeFarm," nesta, accessed September 14, 2020, https://www.nesta.org.uk/feature/ai-and-collective-intelligence-case-studies/wefarm/.

3.
The Potential Downside: Challenges and Risks

While these values can be important to development efforts, all emerging technologies bring with them challenges and risks. As Calestous Juma identifies in his book *Innovation and Its Enemies: Why People Resist New Technologies,* new technologies can spark resistance when actors fail to appreciate the ways technology challenges continuity, social orders, and stability.[77] Organizations need to consider the ways technology can harm themselves and intended beneficiaries.

Some of these threats will be known from the outset of any project and are common to all technological solutions. Though each of these elements manifest different for each of the 4Is (as discussed below), major themes include:

- ***Technological determinism and solutionism,*** including a tendency to frame issues as engineering problems and to prefer the novel and technological solutions over tested methods. Some technology-driven projects can absorb more resources than what they produce and adaptation costs can draw attention away from more pressing development problems;
- ***Increasing social and economic inequalities and social fragility*** through unequal access to technology and disruptions to social bonds and economic sectors. At worst, a failure to consider power asymmetries or control for inequities can result in a kind of data colonialism in which the data of people in developing countries is extracted by outside organizations;[78]
- ***Less transparent and participatory decision making*** as algorithms take over functions from human operators in assessing eligibility for aid, conducting service delivery, analyzing complex datasets for decision-makers, or managing other operations. Some organizations might seek to avoid accountability by either blaming automated processes when errors occur or concealing how decisions are made using black box algorithms; and
- ***Increased polarization and political manipulation*** as new technologies can allow for rapid dissemination of misinformation or disinformation, create ideological echo chambers, and shield hyper-targeted political messaging from public scrutiny.
- ***Overreliance on technology platforms, systems, or vendors*** as new technologies are too costly to manage or maintain by local actors or require training inconsistent with local interests. Intended beneficiaries can, intentionally or unintentionally, become dependent on the providers of a technology, rendering the resource non-viable in the long term.

Since there is often a lag between the development of new technologies and an understanding of their risks, some potential harms may not be known, and the balance of risk and reward may be difficult to measure. Development practitioners must therefore carefully consider known risks and monitor for emerging negative externalities of technologies. If a negative consequence emerges or seems likely to emerge, organizations need to discuss internally whether to continue pursuing the project, implement mitigation measures, or terminate the project.

When considering implementation of the 4Is, practitioners should be cognizant of these specific risks and challenges. They should also consider whether they can be mitigated and at what cost.

Data Intelligence

- **Challenges**
  - *Ensuring Sustainability:* Development contexts are often resource-poor settings. The lack of well-developed infrastructure or foundational education, knowledge, and skill can be a challenge for implementation. Organizations may need to develop existing systems, which can require significant investments in development, training and human resources. They also need to develop project metrics that can allow them to demonstrate the effectiveness of interventions, as many initiatives launched in developing countries fail to produce results that justify their existence. As the Web Foundation notes, a common problem affecting open data initiatives across Africa is that they often suffer restricted or reduced funding after their initial launch, undermining capacity.[79]

77 Juma, Calestous. *Innovation and Its Enemies: Why People Resist New Technologies.* 1st edition. New York, NY: Oxford University Press, 2016.

78 Coleman, Danielle. "Digital Colonialism: The 21st Century Scramble for Africa through the Extraction and Control of User Data and the Limitations of Data Protection Laws." *Michigan Journal of Race & Law* 24 (2019 2018): 417.

79 Web Foundation, "Africa Data Revolution Report 2018: Status and Emerging Impact of Open Data in Africa," http://webfoundation.org/docs/2019/03/Africa-data-revolution-report.pdf.

- *Data Security:* Data-driven projects can involve personally identifiable information (PII) with implications for individual privacy and, in some contexts, security. It might also be possible to infer an individual's personal identity through the data or by combining multiple sources. Consequently, organizations must be cognizant of their data management practices to ensure the data is not compromised by a malicious party during storage, sharing, or use.

- *Outreach and Data Consent:* Organizations can struggle to obtain meaningful consent to collect data because of a lack of adequate infrastructure or a lack of data literacy among data subjects. Data subjects, meanwhile, can struggle to engage with organizations if they are given inadequate information to understand what they are agreeing to or otherwise intentionally not informed about the full scope of a project. Data-driven organizations have an obligation to seek consent and to remain aware of the power imbalance between themselves and aid recipients. They also must ensure data use coheres with local expectations

- **Risks**
  - *Surveillance and Exploitation:* Data tools can help the powerful to surveille and control the powerless. In all their work, organizations need to think critically about for whom their work is a source of protection and for whom it poses danger.

  - *Privacy Risks:* A 2019 study of consumer IoT devices in the US and the UK found many cases in which information was sent to third parties without the users' awareness of who these parties were or what data was being collected.[80] It is unclear how prevalent this problem is in the Global South, but some private datasets used for data collaboration, similarly, can possess sensitive information that can cause harm if exposed.[81] Recently, a platform commonly used by aid agencies was found to have security problems that exposed personal and financial data about thousands of humanitarian aid beneficiaries.[82]

  - *Data Quality and Bias:* The value of data-driven projects depends on the quality of the information. Though all projects are flawed, organizations should seek to mitigate risk by thinking through how alternative data sources replicate or perpetuate existing biases. They should also ensure that the information they use is sufficiently accurate, relevant, granular, and up-to-date to inform the decision they wish to make. When gaps emerge, such as an under-representation of women, older people, and rural or low-income communities, parties ought to be transparent in the risks these gaps cause. Promising data-driven initiatives can be rendered obsolete by irregular or inconsistent data collection practices or poor management of data resources.[83]

  - *Open Washing:* Partner organizations may seek alternative data sources to avoid more difficult transparency efforts. As such, organizations should consider the motives of any organization they wish to collaborate with to ensure they are not legitimizing a bad actor. Though not directly related to emerging technologies, the Extractive Industries Transparency Initiative—a global governance standardization effort backed by governments, corporations, and financial institutions to promote open data and accountability in natural resource management—has suspended member countries to avoid legitimizing actors who have joined for prestige but not undertaken any reforms.[84]

  - *Legitimacy:* A recurring problem for many initiatives is a tendency to overpromise and

80 Jingjing Ren, et al, "Information Exposure from Consumer IoT Devices: A Multidimensional, Network-Informed Measurement Approach," *IMC '19: Proceedings of the Internet Measurement Conference,* October 2019, https://moniotrlab.ccis.neu.edu/wp-content/uploads/2019/09/ren-imc19.pdf

81 "Orange Telecom Data for Development Challenge (D4D)," DataCollaboratives.org, https://datacollaboratives.org/cases/orange-telecom-data-for-development-challenge-d4d.html

82 Parker, Ben. "Security Lapses at Aid Agency Leave Beneficiary Data at Risk." The New Humanitarian, November 27, 2017. https://www.thenewhumanitarian.org/investigations/2017/11/27/security-lapses-aid-agency-leave-beneficiary-data-risk.

83 Ministère de L'Education Nationale, de l'Alphabétisation et de la Promotion des Langues Nationales. "Nos Écoles, Nos Donnees," 2019. https://nendo.gov.bf/.

84 Reuters Staff. "Azerbaijan Leaves Transparency Group after Membership Suspended." *Reuters,* March 11, 2017. https://www.reuters.com/article/us-azerbaijan-eiti-idUSKBN16I007.

underdeliver. Aside from the ethical problems of misleading those in sensitive contexts, the result is disillusionment among subjects and a loss of legitimacy. As such, before communicating with the public, organizations should think critically about what they can realistically provide and what obstacles might make their goals difficult to achieve.

Artificial Intelligence

- **Challenges:**
  - *Data Access and Preparation:* AI systems rely on training data and significant computing power. Especially in poor countries high-quality, timely, and accessible data is often not available.[85] Generating or otherwise gaining access to this data can entail investment in data collection technologies or forging partnerships with data-holding or data-generating collaborators. AI project organizers also face time and cost commitments in the cleaning, processing, and preparation of that data for training purposes.

  - *System Decay:* AI systems are effective in solving highly specific problems. Once those problems are solved or a new, more pressing issue arises, AI systems cannot typically transition to new objectives. Thus, an investment in an AI system is often a commitment to a particular problem or objective for an indefinite period. A new focus or priority will necessitate significant investment in new AI training and development, as well as training for human actors engaging with AI systems. While transfer learning, which aims at transferring obtained knowledge to different, but related problem settings, is an area of active research, such approaches are more nascent.

  - *Infrastructure:* Training AI models often requires costly infrastructure. Such infrastructure is typically not available in developing countries. Thus, organizations must either be sure to have sufficient funding to build up this infrastructure or team up with partners who can provide it.

- **Risks**
  - *Ethical Fading and Impact on Livelihoods:* AI systems may lead to decisions focused on financial or practical considerations instead of ethical reasoning.[86] Generally, ML will minimize a certain cost function (or optimize a reward function) without considering other constraints, such as ethics, unless they are explicitly stated in the cost function. This is especially an issue when development agents are not sufficiently integrated in the design process of the algorithm.

  - *Opaque Decision-making:* Many ML methods, especially those based on neural networks, can typically only be treated as black-box systems, but there is little hope of interpreting the outcomes or understanding how they arrived at their decisions. That way, AI can introduce ambiguity and bias into decisions that make accountability difficult to maintain.[87] A way around that problem is the use of explainable AI (XAI) methods.[88] However, especially in the field of deep learning, such methods are not as well developed yet.

  - *Bias, Discrimination, and Loss of Dynamism:* The output of an AI algorithm is determined by its design and its input data (and, depending on the algorithm, potentially some stochasticity). This implies that the algorithm will not be able to handle special cases that might be obvious to a human operator or certain operators (e.g. people of color) if they were not represented in the design process.[89] ML approaches will

85 J. L. Cohen and H. Kharas, "Using big data and artificial intelligence to accelerate global development," Brookings Institution, 2018. https://www.brookings.edu/research/using-big-data-and-artificial-intelligence-to-accelerate-global-development/

86 Yazeed Awwad, et al, "Exploring Fairness in Machine Learning for International Development," MIT D-Lab Comprehensive Initiative on Technology Evaluation, March 2020, http://d-lab.mit.edu/sites/default/files/inline-files/Exploring_fairness_in_machine_learning_for_international_development_03032020_pages%203.pdf

87 Yazeed Awwad, et al, "Exploring Fairness in Machine Learning for International Development," MIT D-Lab Comprehensive Initiative on Technology Evaluation, March 2020, http://d-lab.mit.edu/sites/default/files/inline-files/Exploring_fairness_in_machine_learning_for_international_development_03032020_pages%203.pdf

88 W. J. Murdoch et al, "Definitions, methods, and applications in explainable machine learning," Proceedings of the National Academy of Sciences, October 2019. https://www.pnas.org/content/pnas/116/44/22071.full.pdf

89 Yazeed Awwad, et al, "Exploring Fairness in Machine Learning for International Development," MIT D-Lab Comprehensive Initiative on Technology Evaluation, March 2020, http://d-lab.mit.edu/sites/default/files/inline-files/Exploring_fairness_in_machine_learning_for_international_development_03032020_pages%203.pdf

further reflect the human input biases they have encountered in the training data.[90] These mistakes often fall on at-risk groups who might be underrepresented or misidentified in the data.[91] The World Economic Forum's *How to Prevent Discriminatory Outcomes in Machine Learning* describes a hypothetical case in which an AI deployed in Kenya might use digital footprint in deciding whether or not to loan money to individuals, preventing rural Kenyans with less access to digital infrastructure from securing access to money.[92]

- *Correlation vs Causation:* Current machine learning approaches mostly learn correlations, but not causal relations. Thus, policies or models obtained through machine learning techniques will most likely also include spurious correlation found in the training data. This lowers the explainability and interpretability of those policies or models and makes them particularly vulnerable when extrapolating outside their training domain.[93]

- *Environmental Damage:* The infrastructure needed to train AI, and especially ML, algorithms, draws significant energy. If this energy is gained through burning fossil fuels, this increases CO^2 output.[94]

- *Deepfakes:* As any technology, AI can be abused. One such example is the emergence of "deepfakes." Deepfakes involve deep neural networks used to create false video and audio representations of real persons. With the advances in machine learning, it has become hard to distinguish between deepfakes and the real audio and video recordings. Such techniques have, supposedly, been used in Gabon to create a video of president Ali Bongo, who had been unseen for a long time and believed to be in poor health conditions or dead. This video was cited as the trigger for a coup of Gabon's military (which was unsuccessful).[95]

- *Inclusiveness:* While AI has the potential to automate repetitive, routine tasks to free workers to spend their time with more useful tasks, it can also be used to replace low-skilled workers. Also, since successfully implementing AI algorithms requires some training and education, lower educated people might be excluded from its potential benefits.

Collective Intelligence

- **Challenges**
  - *Information Processing and Triage:* CI provides a distributed crowd the chance to contribute information through a central channel. Project organizers can face significant costs associated with managing and deciphering these contributions.[96] The inclusivity of collective intelligence projects can also increase the number of participants and thus the amount of noise in the system, an operational burden organizers must direct resources toward addressing.[97]

  - *Communications, Outreach, and Participation Management:* CI organizers, in addition to creating or partnering with the creator of a platform, must entice public participants. Organizers must promote the engagement, coordinate with participants throughout the project, and communicate publicly about

90 Ludovic Righetti, Raj Madhavan, and Raja Chatila, "Unintended Consequences of Biased Robotic and Artificial Intelligence Systems," *IEEE Robotics & Automation Magazine,* September 5, 2019, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8825881

91 Ludovic Righetti, Raj Madhavan, and Raja Chatila, "Unintended Consequences of Biased Robotic and Artificial Intelligence Systems," *IEEE Robotics & Automation Magazine,* September 5, 2019, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8825881

92 Global Future Council on Human Rights 2016-2018. "How to Prevent Discriminatory Outcomes in Machine Learning." White Paper. World Economic Forum, 2018. http://www3.weforum.org/docs/WEF_40065_White_Paper_How_to_Prevent_Discriminatory_Outcomes_in_Machine_Learning.pdf.

93 Bernhard Scholkopf, "Causality for Machine Learning," arXiv, December 23, 2019, https://arxiv.org/pdf/1911.10500.pdf

94 Karen Hao, "Training a single AI model can emit as much carbon as five cars in their lifetimes," MIT Technology Review, June 2019. https://www.technologyreview.com/2019/06/06/239031/training-a-single-ai-model-can-emit-as-much-carbon-as-five-cars-in-their-lifetimes/

95 Mika Westerlung, "The Emergence of Deepfake Technology: A Review," Technology Innovation Management Review, November 2019. https://timreview.ca/article/1282

96 Dietmar Harhoff and Karim R. Lakhani (eds.), Revolutionizing Innovation: Users, Communities, and Open Innovation.

97 Joshua C. Gellers, "Crowdsourcing global governance: sustainable development goals, civil society, and the pursuit of democratic legitimacy," *Int Environ Agreements,* 2016.

outcomes of the effort. These steps all have implications on staffing budgets and time commitments. Additionally, CI can suffer from public suspicions that their input will not be acted upon. Research demonstrates the importance of establishing clear feedback loops that show participants that their contributions are, if not always acted upon, at least considered as part of a fair process.[98]

- *Process Design, Implementation, and System Change:* While institutions may experiment with CI without integrating more participatory mechanisms into their standard operations, The GovLab report *Solving Public Problems with Collective Intelligence* argues that sustained engagements will likely require practitioners to "adapt long-standing procedures, shift organizational cultures, foster conditions more conducive to external partnerships [...] and ensure collective intelligence inputs are transparently accounted for when making decisions."[99] These commitments can be costly but can produce new, long-term insights across an organization's operations instead of just on a few limited test cases with little potential.

- **Risks**
  - *Privacy, Security, and Ethics:* CI projects are generally less susceptible to privacy risks, but these risks are not nonexistent. Individuals can share personal data when registering for an online platform, share potentially contentious viewpoints in crowdlaw projects, or, perhaps most troublingly, share granular information about their location through community mapping platforms or other technologies that capture and report users' geolocation. Outside the development context, one exercise company's decision to map (what it assumed to be) innocuous exercise paths of users around the globe accidentally revealed the location of sensitive military installations.[100]
  - *Groupthink:* In more deliberative CI, a group's viewpoints can consolidate inorganically due to the project's structure (e.g. only permitting individuals to agree with particular statements rather than respond) or engagements that allow for the loudest or most influential voices to dominate. Geoff Mulgan, Chief Executive of Nesta, a UK innovation foundation warns, "shared assumptions that don't hold true, a shared willingness to ignore uncomfortable facts, groupthink, group feel, and mutual affirmation rather than criticism."[101]
  - *Unpaid Labor:* Some CI can be overly extractive if they are not designed in a human-centered manner. Many AI and CI platforms rely on large numbers of low-paid, invisible laborers working in inferior conditions. Such labor is unacceptable and inconsistent with development goals. Labor for the co-creation or development of institutional or global goods, especially in least-developed contexts, must be met with some type of direct incentive or reward.[102]
  - *Manipulation:* A major challenge facing CI projects is anticipating and mitigating agenda-motivated manipulation by participants, project sponsors, and other actors, especially in environments moderated by online platforms. Certain communication tools (e.g. social media) can create opportunities for participants to be deceived through false and inflammatory content, subject to propaganda, or drowned out by bots. As such, CI projects often cannot run autonomously but need to be subject to constant second-level monitoring and assessment or, at the very least, prefaced with attempts to model the risks facing the project and participants. Organizations need to be aware of the ways their work interacts with political fissures and the ways a platform (and the assumptions baked into its design) may exacerbate those tensions.

98 Helen K. Liu, "Crowdsourcing Government: Lessons from Multiple Disciplines," *Theory to Practice,* July 13, 2017, https://onlinelibrary.wiley.com/doi/full/10.1111/puar.12808.

99 Matt Ryan, Beth Simone Noveck, and Peter Baeck, "Solving Public Problems with Collective Intelligence: how institutions can work together," The GovLab, November 19, 2019, http://thegovlab.org/solving-public-problems-with-collective-intelligence-how-institutions-and-crowds-can-work-together/

100 Hsu, Jeremy. "The Strava Heat Map Shows Even Militaries Can't Keep Secrets from Social Data." Wired, January 29, 2018. https://www.wired.com/story/strava-heat-map-military-bases-fitness-trackers-privacy/.

101 Geoff Mulgan, Big Mind: How Collective Intelligence Can Change Our World.

102 Evangelia Berdou, "Open development in poor communities: Opportunities, tensions, and dilemmas," Information Technologies & International Development, 13.

Embodied Intelligence

- **Challenges**
  - *Limited knowledge base:* EI implementations, especially in a development context, are still nascent, with limited established knowledge and practice to inform future practices. Unlike the other forms of intelligence discussed here, development practitioners experimenting with EI are likely to forge new territory with few use cases to emulate or evidence to draw upon.

  - *Upfront expense:* The nascence of EI technologies also, unsurprisingly, result in upfront costs that can be prohibitively high. Especially in development contexts, these cost burdens could outweigh the potential value an EI implementation could generate in the long or short term. Practitioners should always seek to identify what unique value a technology provides and assess whether an outcome can be achieved more easily and cheaply through conventional means.

- **Risks**
  - *Diminished agency:* EI introduces risks to human agency and workforce retention similar to that of AI. That is, EI taking over tasks can lead to replacement of (especially low-skilled) workers. Research has indicated, however, that investments in skillbuilding can help transition displaced workers to more operational and oversight roles. Indeed, researchers from the London School of Economics found that industrial robots can help to increase productivity and the number of low-skilled jobs in some contexts.[103]

  - Environmental damage: With proper maintenance, robots, drones, and 3-D printers all have the potential to last for a number of years. However, once they are ready to be replaced — whether due to damage or inevitable obsolescence — it is likely that they will contribute to the persistent problem of electronic waste, called by some observers "the fastest growing waste stream in the world."[104]

103 Georg Graetz and Guy Michaels, "Robots at Work," *MIT Press Journals,* 2018, http://personal.lse.ac.uk/michaels/Graetz_Michaels_Robots.pdf

104 World Economic Forum, "A New Circular Vision for Electronics, Time for a Reboot," January 2019. https://www.weforum.org/reports/a-new-circular-vision-for-electronics-time-for-a-global-reboot

4. Conclusion: Making the Intelligence Paradigm Operational

In the above, we describe the pros and cons of emerging uses of technologies for development and the forms of intelligence those use cases can produce. In conclusion, we seek to demonstrate how practitioners can move beyond mere consideration. This section provides recommendations to make this paradigm operational for both implementing partners and a funders. First, we provide a series of recommendations based on factors common in successful projects associated with each of the four paradigms. These recommendations are integral to appropriate implementation. In the second part, we provide a decision-making framework to determine whether to invest in emerging technologies and if such technologies are appropriate and can effectively support development objectives. This section is useful in evaluating the merits of a proposal.

Each of these recommendations is derived from the preceding analysis and discussion, as well as from a wealth of empirical evidence and real-world applications, some of which we have discussed in this paper.

4.1 – Intelligence-Specific Recommendations

Data Intelligence

- ***Use Collaborative Agenda Setting:*** Data can be useful for a variety of emerging technologies, but collection can be a costly and time-consuming process, especially in settings where an organization has little prior expertise. To lessen costs, organizations might seek to focus their efforts on one specific issue. Instead of seeking all information about an area, development organizations can work with local actors (such as local government, civil society groups, and intended aid recipients themselves) to define what question they hope data can answer.[105] This collaborative agenda-setting process can be complimented with an audit of data assets and expertise, one that allows development practitioners to understand what data and expertise they and their partners already possess.
- ***Identify Intended Beneficiaries:*** Ensuring use of insights that emerge from data can be even more resource intensive. Before beginning work in an unfamiliar context, development actors can map who their target audience is and whether there are any local trusted groups who can speak for them and legitimately represent their interests. Allowing this group to guide the project throughout the data lifecycle can ensure those who could benefit from the data trust its source, have an interest in sustaining it long-term, and see the application as legitimate. It can also be useful for training, ensuring all actors understand how to use the data, interpret products made from it, and use data-driven tools independently.
- ***Connect Pilots:*** While several emerging technologies have yet to be successfully implemented on a large scale in development contexts, there have been pilots and experiments that point to their value. Connecting the findings of these disparate pilots to better understand methods, risks, and outcomes is essential to creating a common knowledge base, one that can support large, successful deployments of emerging uses of technology. Development actors might seek opportunities to break down information silos by keeping track of and compiling documents from projects from various development actors and grantees. They might also seek to support the development of detailed case studies to publicize their own work and to allow others to learn from their successes and mistakes. Through this work, organizations can build on what came before them.

Artificial Intelligence

- ***Ensure Availability and Robustness of Necessary Data:*** Currently hyped AI techniques (e.g. machine learning methods based on deep neural networks) typically require large amounts of high-quality data. When deploying such methods, organizations must recognize that the quality of any AI or ML model is only as good as the input data. Thus, they need to check that the necessary quantity and quality of data are available before committing to the proposed solution or risk an undesirable outcome. Especially in developing countries,

105 For an example of a project that uses collaborative question development, please see: https://the100questions.org/

critical data is often not readily available[106]. Less popular but more data-efficient methods that also provide a higher interpretability (e.g. methods based on probabilistic inference) may offer an alternative. However, these higher interoperability methods can fail when parsing large amounts of data as they are computationally more expensive.

- **Adopt Holistically:** Occasionally, organizations view AI as a panacea, a tool that can be plugged into any project to improve it. However, AI is more than its hype. It has significant needs. While some of these needs are technical (discussed above), they are also organizational. Using AI effectively requires organizations to have a strategy, culture, and governance structure that can harness it. If there are no internal advocates for the too, it is unlikely to be useful for external stakeholders.

- ***Acknowledge Risks Involved in Relying on Infrastructure Provided by Third Parties:*** Since AI methods usually involve high computational costs, computations are often outsourced to servers managed by third parties. In such cases, development actors will need to take additional steps to confirm that any sensitive data is securely and responsibly handled by all parties. Such steps could include ensuring that data is encrypted, that sensitive data is only accessible for authorized users, or negotiating a contract with all involved parties (as many jurisdictions already require by law). However, even if an actor is storing and processing data itself, it is often a best practice (and legal requirement) to ensure sensitive personal data is only accessible to authorized parties. Further, third parties that are capable of maintaining such costly infrastructure are typically large companies. It is then also important to ensure that development actors do not unintentionally serve to embed the economic or political agenda of these companies. The United Nations World Food Programme (WFP), for instance, has been criticized for its partnership with a US defense contractor to reduce operational costs. Some worry that this criticism could negatively impact how beneficiaries and other stakeholders view the institution from an ethical perspective.[107]

- ***Augment But Don't Replace Human Workers:*** AI methods can enhance automation, thus, increasing efficiency of, for example, manufacturing companies. On the other hand, this may result in reduction of low-skilled labor. While AI also offers new job opportunities, these are oftentimes limited to highly educated people who are often not from the communities where the technology is deployed. Thus, efforts need to be made to ensure that the transition toward increased adoption of AI methods happens in an inclusive manner.[108]

Collective Intelligence

- ***Combine Artificial Intelligence and Collective Intelligence:*** CI projects, particularly those deployed on a large scale, can generate dozens, hundreds, or thousands of user submissions in a short period of time. The organizers of these projects can face significant information management challenges, with difficulty identifying the signal in the noise of user contributions. Depending on the amount of detail accommodated by the project design model, development practitioners could prioritize uses of collective intelligence with well-defined approaches for managing participant inputs—including the use of AI to help triage contributions in larger-scale projects. Deciding what constitutes noise and what is meaningful can be done with collective input to avoid bias and over-simplification.

- ***Determine Whether New Technology Is Necessary:*** Technology-enabled CI, perhaps more than any other intelligence discussed in this paper, represents a transition from longstanding in-person and analog processes into the digital realm. In many cases, technology can be essential in either achieving the scale necessary for achieving a given solution, such as an extensive participatory mapping exercise. In other cases, technology can be superfluous, or even counterproductive in achieving desired objectives — such

106 S. Telford, "The State of Open Humanitarian Data 2020," Centre for Humanitarian Data, January 2020. https://centre.humdata.org/the-state-of-open-humanitarian-data-2020/

107 Parker, Ben. "New UN Deal with Data Mining Firm Palantir Raises Protection Concerns." The New Humanitarian, February 5, 2019. https://www.thenewhumanitarian.org/news/2019/02/05/un-palantir-deal-data-mining-protection-concerns-wfp.

108 O.-C. Pham, et al, "The Impact of Robotics and Automation on Working Conditions and Employment, *Ethical, Legal, and Societal Issues*, June 13, 2018, https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=8385401.

as in cases where the target population is not connected to the Internet. Development practitioners can improve the effectiveness of CI if they assess the audience they wish to engage and determine the most effective medium through which to reach them — which could include new technology platforms, simple SMS messaging, or traditional offline engagements like town hall meetings.

- ***Use CI to Gauge Perceptions on Emerging Uses of Intelligence:*** Deliberative CI approaches like digital citizen assemblies can help make stakeholders aware of public perceptions on various topics. As it stands, development practitioners often lack nuanced understanding of how people view different emerging uses of technology in their communities. In the interest of going beyond reductive public opinion surveys, development actors could look to digital citizen assemblies models to gauge public perceptions and preferences regarding the use of various emerging technologies, including those outlined in this work.

Embodied Intelligence

- ***Pursue Local Engagement:*** EI tools are effective at conducting tasks that would be difficult, costly, unsafe, or impossible for human laborers to conduct. This value can be substantial but it ought to be conducted for the benefit of others, not as a good in and of itself. Development actors ought to consider how EI can assist humans, for example, by freeing them to conduct more complex and meaningful tasks or by providing recommendations, instead of simply replacing them or forcing them to keep up with the faster pace of robots or drones. This development process can be conducted in coordination with local actors with public constituencies who can ensure work is useful and legitimate and does not occur at the expense of vulnerable individuals.

- ***Map Enablers of Success and Failure:*** Moreover, automation necessarily reduces agency and the capacity of actors to respond to individual factors. This can increase the possibility of unintentional harms, with automated processes repeating patterns without consideration of unforeseen circumstances. In addition to developing oversight mechanisms that can ensure safe operation, development actors might, in coordination with local actors, seek to map out all the circumstances that could affect the project positively or negatively. If the possible negative consequences are severe, participants can reassess whether the project is still useful or develop procedures to mitigate potential harm. One such way can be to decrease the level of automation and pull humans back into the loop. Clearly, the project should then be regularly re-evaluated as the technology and the associated risks and challenges evolve.

- ***Assess Capacity:*** EI tools remain little-used in development contexts and, as such, have large launch and maintenance costs. Development actors might seek to assess local capacity before funding an embodied intelligence project. In addition to assessing infrastructure, technical skills among the workforce, and community support, this assessment process should look critically at governance. If there are no policies or guidelines that can ensure safe and appropriate use, development practitioners might work with legitimate local actors to develop these principles for the planned and future work.

4.2 – Principles and Considerations: When to Consider Emerging Technologies

Given all these recommendations, the question still remains: When can emerging technology provide new insights to achieve a development goal? Inspired by the examples collected and aligned with the *Principles for Digital Development,* this section outlines some of the criteria to use as to determine whether to consider the use of emerging technology to address development objectives (as opposed more traditional or local means).[109]

Understanding the multitude of criteria affecting a project, this section does not provide any hard, quantified numbers to apply in all cases. Rather, through the use of questions, it invites development practitioners to think critically about the context in which they operate. Practitioners might convert the

109 Principles for Digital Development. "Principles." Digital Principles, 2020. https://digitalprinciples.org/.

elements of this section into an evaluation grid to assess whether their project is:

4.2.1 – Fit for Purpose: Does the use of technology address a clear, well-defined issue in a way that matches the proposed value proposition and resonates with the targeted beneficiaries?

Emerging technology for development projects need to specify a clear ***WHO*** (a group in need of support); be able to articulate ***WHAT*** the technology intends to address (some existing gap or failing that matters to the target group); and ***HOW*** the technology will address that cause. It also needs to explain ***WHY*** this approach has value over other responses that do not use emerging technologies.

Legitimate local stakeholders can facilitate this problem definition work, verifying the application will be meaningful and legitimate for its intended audience. We strongly discourage organizations from developing top-down solutions—bringing in foreign experts to implement complex, unsustainable solutions—and instead encourage practitioners to look for cases where there is local demand for a selected tool.

- **Data Intelligence:** The Government of Kenya developed the National Farmers Information Service with a clear audience (rural farmers) and what that group needed (easy access to commodity prices). The service's ability to fill a gap in the existing information chain and augment local capabilities contributes to its continued use.
- **Artificial Intelligence:** The University of Nottingham and the United Kingdom's Department for International Development's road condition survey project also directs itself to address the needs of a local actor (Tanzanian commuters). It facilitates official efforts to improve travel through the use of machine-learning algorithms that can identify road quality.[110]
- **Collective Intelligence:** Jamaica's Interactive Community Mapping project, discussed above, uses collective intelligence to spread the economic benefits of tourism. By using local actors who understand local problems, the project could better use technology (the OpenStreetMap platform) to map the country and identify localized opportunities and needs.[111]
- **Embodied Intelligence:** The Rwandan solar company Great Lakes Energy designs electricity provision systems for orphanages, schools, and embassies. These systems must, by necessity, be customized—designed with input from the intended users on their circumstances.[112]

4.2.2 – Cost: Is the project cost effective to establish and sustainable to maintain over the long term given the resources available to the practitioner and their partners?

Emerging uses of technology for development, even those that rely on a mature technology, can be costly to implement on a large scale. As such, development practitioners face two requirements. First, they are called to determine that the emerging tool is the best way to achieve a development objective, that, for instance, resources spent on installing sensors on water pumps could not be better spent training villagers to repair them. Second, they are asked to assess available resources among them and their partners against operational costs. If most funds will go to setting up the service or technology but cannot be sustained over time and there are no opportunities to reduce expenses (e.g. reusing data, infrastructure or other assets), participants might be better suited exploring different arrangements. For example:

- **Data Intelligence:** In Colombia, the Ministry of Agriculture and Colombian Climate and Agricultural Sector worked with Clima y Sector Agropecuario Colombiano to provide farmers with data on the economics and agronomy of rice cultivation. The organizers weighed the cost of initial investment against increased production and found the project yielded an estimated USD 3.6 million in savings.[113]
- **Artificial Intelligence:** In Nigeria, the fintech Kudi.ai developed a chatbot that enables citizens to access financial services.[114] The chatbot works

110 Simpson, Lea. "Frontier Technologies: The Story So Far." UKAID, 2019. https://indd.adobe.com/view/93905665-ef29-4d41-92e2-c49eb4507b3a.

111 Young, Andrew, and Verhulst Stefaan. "Jamaica's Interactive Community Mapping." ODImpact, January 2016. http://odimpact.org.

112 Great Lakes Energy. "Great Lakes Energy," 2020. http://gle.solar.

113 "Climate Modeling Empowers Farmers | Data Impacts." DataImpacts.org, February 2017. https://dataimpacts.org/project/climate-modeling/.

114 Kudi. "Home Page," 2020. https://kudi.com/.

on popular messaging apps (e.g., Facebook Messenger). The ability to use existing infrastructure and assets which allows it to operate at low cost in a way broadly accessible to the target audience.[115]

- **Collective Intelligence:** sourceAfrica is an investigative tool developed and maintained by ANCIR, Africa's largest association of investigative newsrooms. ANCIR created this repository of 115,000 documents contributed by 137 individuals intended for investigative journalism. The ability to reuse its infrastructure, and assets allows organizations and professionals to reduce their costs while seeking common goals.[116]
- **Embodied Intelligence:** Seeking to test ways to improve long-term agricultural productivity in Uganda, a technology nonprofit supported by the Bill & Melinda Gates Foundation provided drones to farmers to help them better monitor and grow crops. Initial findings from the work found that farmers gained an average of USD 2,150 in incremental annual profits from the initial investment.[117]

4.2.3 – Risks/Benefits: Does the project's proposed value outweigh the possible risks it generates?

We further recommend project sponsors weigh prospective benefits against negative consequences. By engaging with local stakeholders and domain experts, organizations can better assess both whether the project addresses some immediate need, whether there are other means to achieve the goal, and develop frameworks to mitigate risks that might result from it. For example:

- **Data Intelligence:** The D4D Challenge was an international competition in which Orange Telecom offered its anonymized data to researchers seeking to address development problems in Côte d'Ivoire and Senegal. Understanding the risks the project presented to privacy and individual security but interested in realizing the value the project could produce, Orange developed an independent council of experts to assess projects that presented possible ethical risks and develop frameworks for responsible use.[118]
- **Artificial Intelligence:** A Nigeria-based start-up uses machine learning techniques to fuse data from proprietary electronics sensors (e.g., moisture, nutrients, pH).[119] Understanding how resource limitations of its audience could blunt impact, the start-up's sensors are low-cost devices and the only operating requirement is for the user to have internet access to sign onto a cloud server.
- **Collective Intelligence:** Anti-Deforestation App Cambodia is a mobile and web app that enables residents to collect evidence of illegal land use and logging in the Prey Lang forest. The platform is primarily targeted for use by existing forest rangers tasked with identifying and promoting enforcement of anti-deforestation activities and collecting evidence of illegal activity. This focus can help to mitigate risks related to members of the general public reporting false negatives or sharing potentially risky, PII, or images of individuals.
- **Embodied Intelligence:** The 3d4AgDev initiative, supported by the Bill and Melinda Gates Foundation and others, is using 3-D printing and participatory design sessions to create labor saving tools for women smallholder farmers in Malawi.[120] The program enables participating farmers to design and develop tools based on their unique circumstances and needs. The effort not only relies on relatively cheap materials, but by designing with beneficiaries rather than for them, there is little risk that the tools and technologies produced will not provide real-world value.

4.2.4 – Local Assets: Does the target country have the infrastructure and expertise needed to support the technology and, if not, can the project foster that capacity?

Like any tool, emerging technologies can only be effective if used by stakeholders with technical capacity and expertise. A high-tech, complex

115 Brandusescu, A., J. Ortiz, and D. Thakur. "Artificial Intelligence: Starting the Policy Dialogue in Africa." *Washington, DC: World Wide Web Foundation*, December 2017. http://webfoundation.org/docs/2017/12/Artificial-Intelligence-starting-the-policy-dialogue-in-Africa.pdf.

116 "SourceAFRICA," 2020. https://dc.sourceafrica.net/.

117 TechnoServe, "Can Drones Change Africa's Agricultural Future?," TechnoServe (TechnoServe, July 22, 2020), https://www.technoserve.org/blog/can-drones-change-africas-agricultural-future-2/.

118 Verhulst, Stefaan, and Andrew Young. "Orange Telecom Data for Development Challenge (D4D)." Data Collaboratives, 2018. http://datacollaboratives.org/cases/orange-telecom-data-for-development-challenge-d4d.html.

119 Ekekwe, Ndubuisi. "Zenvus – Intelligent Solutions for Farms." *Startup Info* (blog). Accessed October 7, 2020. https://startup.info/zenvus/.

120 Zewdy Gebremedhin, Prof. Charles Spillane, Dr. Una Murray. "Labour Saving Technology to Empower Women Smallholder Farmers." CGIAR Research Program on Climate Change, Agriculture, and Food Security, April 17, 2015, https://ccafs.cgiar.org/news/labour-saving-technology-empower-women-smallholder-farmers.

"solution" imposed by outside actors in response to what they perceive as a "problem" without any consideration for local expertise, money, and technology is unlikely to be useful or sustainable. Local stakeholders from the public sector, civil society, academia, and small- and medium-sized enterprises need to be involved in deploying emerging technologies. As such, a necessary precondition for any project is to audit local assets. If lacking, the cost of improvements and training can be factored into decision-making. For example:

- **Data Intelligence:** In Senegal, the international development company Knuper secured access to call detail records data from the telecommunications company Orange as part of its work to measure literacy. In doing so, the company avoided spending resources to develop its own data assets in the country.[121]
- **Artificial Intelligence:** M-Shule is a mobile platform operating in Kenya that delivers lessons based on the country's national curriculum via SMS. The wide availability of SMS-capable devices ensures the platform can reach a large audience.[122]
- **Collective Intelligence:** The Vodafone Foundation's emergency response system in Tanzania relies on a 24-hour telephone line to help women in Sengerama and Shinyaga receive medical treatment. General telecommunications connectivity in the target communities allows the app to receive and respond to a significant number of callers.[123]
- **Embodied Intelligence:** Nairobi's Ultra Red Technologies, as previously discussed, used its existing local capacity to produce face masks to address a shortage of face shields for healthcare workers.

4.2.5 – Governance: Are there policy frameworks and institutions that can meaningfully provide oversight and responsible use?

Projects are rarely simple and can require stakeholders to make complex, technical decisions that affect others' lives. We encourage organizations to assess if both they and the target country have an adequate framework to address risks and ensure responsible use and whether they have an obligation to develop one if either party is lacking it. Neither the most or least developed countries are guaranteed to have clear frameworks with enforceable rules. We further encourage organizations to examine their internal processes and guidelines against these standards to determine whether they themselves can effectively meet a tool's technical, ethical, and professional needs while preserving the rights of data subjects. For example:

- **Data Intelligence:** UN OCHA's Data Responsibility Guidelines provides principles, processes, and tools to help humanitarian actors better manage data throughout their work. Organizations seeking to use data in complex situations might apply this guide to develop their overall approach to data use and develop minimum standards for data responsibility.[124] Additional guidance on data use can be found in the AU–Internet Society Personal Data Protection Guidelines for Africa, which provide 18 recommendations to promote trust and data protection.[125]
- **Artificial Intelligence:** The International Technology Law Association's Responsible AI Policy Framework provides a guide for organizations seeking to use AI systems in a consistent, ethical, and accountable manner.[126] Development practitioners can review this guide to ground their work and address harms that might be caused by AI.
- **Collective Intelligence:** General principles for centering ethics and human rights in technology use can be found in the World Economic Forum's *How to Design Responsible Technology: New Framework for Innovation.* The document provides general guidance to understand how disruptive tools are designed and developed; how they are deployed; and how they are applied. It offers practitioners with questions and other resources

121 https://datacollaboratives.org/cases/knuper-data-upcycling-in-senegal.html

122 Mulligan, Gabriella. "The Startup Bringing AI-Powered SMS-Based Learning to Kenya." *Disrupt Africa* (blog), March 21, 2018. https://disrupt-africa.com/2018/03/the-startup-bringing-ai-powered-sms-based-learning-to-kenya/.

123 Tech Tribes. "Uber like Ambulance System Saves Children and Mothers Lives in Tanzania," 2018. https://techtribes.org/uberambulance/; Petronzio, Matt. "How an 'Uber for Pregnant Women' Is Saving Lives in Tanzania." Mashable, April 15, 2017. https://mashable.com/2017/04/15/vodafone-maternal-health-uber-ambulance/.

124 "OCHA Data Responsibility Guidelines Working Draft." New York: The United Nations Office for the Coordination of Humanitarian Affairs, March 2019. https://centre.humdata.org/wp-content/uploads/2019/03/OCHA-DR-Guidelines-working-draft-032019.pdf.

125 Internet Society. "Personal Data Protection Guidelines for Africa," May 8, 2018. https://www.internetsociety.org/resources/doc/2018/personal-data-protection-guidelines-for-africa/.

126 ITechLaw. "Responsible AI: A Global Policy Framework," June 14, 2019. https://www.itechlaw.org/ResponsibleAI.

to assess their practices.[127] Nesta's *Governing with Collective Intelligence similarly introduces how collective intelligence* can support governments at every level of development and explains the value of expertise drawn from citizens.[128]

- **Embodied Intelligence:** In 2018, the government of Rwanda partnered with the World Economic Forum to co-design a policy framework for drone regulation.[129] It is the first country to do so, and could serve as a model for other countries working towards governance of emerging technologies. Rwanda developed this framework after a successful initiative with the Silicon Valley startup Zipline, using drones for medical product delivery.[130]

4.2.6 – Timeliness: How long will it take for the proposed value to be realized in the target country?

Projects can take time to deploy, even in a high-income context. Parties should ensure they can deliver their solution while the problem remains relevant without having to circumvent legal, ethical, or professional obligations. If not, it might be better to pursue other, more quickly deployed options. For example:

- **Data Intelligence:** As described above, the Burkina Open Data Initiative (Bodi) and the Open Data Institute worked to rapidly compile Burkina Faso's 2015 election results through a public, mobile-responsive web app. This rapid reporting enabled public authorities and the media to share validated vote tallies and to bolster public trust at a time when the government needed it.[131]
- **Artificial Intelligence:** Organizations such as the Sustainability and Artificial Intelligence Lab have attempted to predict crop yield based on satellite imagery. Given growing patterns, this work requires analysts to work rapidly over the months before harvest.[132] This data is fed to a machine learning model, in particular, a convolutional neural network, that outputs a crop yield map. Accurate predictions of the expected crop yield can be used to make more informed planting decisions, set food reserve levels, or identify regions with potentially low yield that need special assistance.
- **Collective Intelligence:** The previously discussed WeRobotics Open AI challenges, like most competitions of this type, seek to rapidly produce pilot projects in response to persistent, tangible development challenges. Its competition in Tanzania, for instance, launched 28 August and ran through 1 November, with subsequent winning entries immediately delivered to the State University of Zanzibar, the Tanzania Commission for Land Planning and other Tanzanian organizations.[133]
- **Embodied Intelligence:** In Lebanon, a file-sharing platform worked with Oxfam to develop a 3-D printing solution that would allow Syrian refugees to sanitize their hands more.[134] The project relied on a large, experienced community of 3-D modelers from around the world who quickly developed designs for the equipment that could be rapidly deployed in the field.[135]

4.2.7 – Maturity: Has the emerging technology been successfully deployed in similar development contexts?

Many emerging technologies receive hype but have limited history in development. We suggest organizations search for prior examples of successful applications that relate to the country, technology, or topic they intend to address. If there is little evidence or if the record of success is mixed, organizations and their local partners can reassess

127 Krieger, Zvika, Pablo Quintanilla, and Hannah Darton. "Responsible Use of Technology." World Economic Forum, August 2019. http://www3.weforum.org/docs/WEF_Responsible_Use_of_Technology.pdf.

128 Tom Saunders and Geoff Mulgan. "Governing with Collective Intelligence." Nesta. January 2017. https://media.nesta.org.uk/documents/governing_with_collective_intelligence.pdf.

129 Catherine, Cheney. "Rwanda Could Become a Model for Drone Regulation." Devex, January 23, 2018. https://www.devex.com/news/sponsored/rwanda-could-become-a-model-for-drone-regulation-91868.

130 "Zipline," 2020. https://flyzipline.com/.

131 Hervé Taoko, and Dionne Searcey, "Burkina Faso Elects First New Leader in Decades," The New York Times, November 30, 2015, https://www.nytimes.com/2015/12/01/world/africa/burkina-faso-elects-1st-new-leader-in-decades.html.

132 Jiaxuan You, Xiaocheng Li, Melvin Low, David B. Lobell, Stefano Ermon, "Combining Remote Sensing Data and Machine Learning to Predict Crop Yield," Stanford Sustainability and Artificial Intelligence Lab, 2017, http://sustain.stanford.edu/crop-yield-analysis/

133 https://blog.werobotics.org/2018/12/06/announcing-the-winners-of-the-open-ai-tanzania-challenge/

134 Srinivas Saripalle, Abi Bush, Naiomi Lundman, "3D printing for Disaster Preparedness: Making Life-saving supplies On-Site, On-Demand, On-Time," *2016 IEEE Global Humanitarian Technology Conference (GHTC)*, 2016, https://ieeexplore.ieee.org/document/7857281

135 MyMiniFactory. "Oxfam," 2014. https://www.myminifactory.com/category/oxfam.

whether to proceed (without any model to follow) or whether to pursue a different approach that might control risks (e.g. engaging with other partners first to test a pilot). For example:

- **Data Intelligence:** Map Kibera, a nonprofit effort to support the Kibera neighborhood in its efforts to map itself, relied on its past experiences to support Kenya's COVID-19 response. The organization has mapped new cases, deaths, and recoveries as they have been announced by the national ministry of health. The information is available online.[136]
- **Artificial Intelligence:** In 2014, researchers sought to apply a belief-rule-based expert system model—which had already been tested in evaluating other e-government services—to local e-governance in Bangladesh. The applied tool proved to be 25% more accurate and reliable than existing methods.[137]
- **Collective Intelligence:** Uganda's Vital Records System (VRS) is a centralized platform for remote communities to register new births with the central government. The system sources records of home births from users at formal healthcare centers and across a network of village-level registration agents. The system operates on Uganda Telecom's 3G network, and registration agents are provided with SIM cards mapped to their name.
- **Embodied Intelligence:** Google's Project Loon launched a fleet of balloons with AI-enabled robotics to deliver 4G LTE network connectivity in remote locations of Kenya.[138] The project is highly experimental but builds on emerging evidence on artificially intelligent robots in a new context and on a larger scale.

136 Mwangi, June. "Map Kibera on COVID-19 Incident and Resource Mapping in Kenya." Ushahidi, April 16, 2020. https://www.ushahidi.com/blog/2020/04/16/map-kibera-covid-19-incidence-and-resource-mapping-in-kenya

137 Mohammad Shahadat Hossain, Pär-Ola Zander, Md. Sarwar Kamal, Linkon Chowdhury, "Belief-Rule-Based Expert Systems for Evaluation of E-Government: A Case Study," arXiv, March 22, 2014, https://arxiv.org/ftp/arxiv/papers/1403/1403.5618.pdf

138 Bethlehem Feleke, "Google Launches Balloon-Powered Internet Service in Kenya," CNN (Cable News Network, July 8, 2020), https://www.cnn.com/2020/07/08/africa/google-kenya-balloons/index.html.

Acronyms and Abbreviations

4G	Fourth generation broadband cellular network technology
AFD	Agence Française de Développement / French Development Agency
AI	Artificial Intelligence
API	Application Programming Interface
Bodi	Burkina Open Data Initiative
CI	Collective Intelligence
CO_2	Carbon Dioxide
CoST	Infrastructure Transparency Initiative
COVID-19	Coronavirus disease 2019
DI	Data Intelligence
DLT	Distributed Ledger Technology
EI	Embodied Intelligence
GPS	Global Positioning System
GPU	Graphics Processing Unit
GSM	Global System for Mobile Communications
IOT	Internet of Things
IT	Information Technology
LTE	Long-Term Evolution
MIT	Massachusetts Institute of Technology
ML	Machine Learning
NGO	Non-Governmental Organization
OCHA	Office for the Coordination of Humanitarian Affairs
OPAL	The Open Algorithms project
PII	Personally Identifiable Information
PLOS	Public Library of Science
SMS	Short Message Service
STAMP2	Sensor Technology and Analytics to Monitor, Predict, and Protect Ebola Patients
UAV	Unmanned Aerial Vehicle
UN	United Nations
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USD	United States Dollar
WFP	World Food Programme

Glossary of Key Terms

3-D Printing: A subset of additive manufacturing, in simple terms, it works by depositing layers of material one at a time until they form a fully realized three-dimensional object.

Artificial Intelligence: A range of techniques that automate activities that are typically associated with, or an extension of, human thinking or thought processes, such as learning, decision-making, visual perception, or natural language processing.

Digital Citizen Assemblies: The use of networked technologies and digital platforms (e.g. collaborative online document drafting systems, video conferencing and synchronous communication platforms) that enable public deliberation and policy co-creation;[139] an online form of longstanding approaches to in-person public deliberation involving randomly selected participants.

Co-Creation and Crowdsourcing: Leveraging networked tools that allow individuals or entities to collaborate to develop and co-create knowledge, ideas, or products. Citizen science, the distributed, collaborative production of scientific research and knowledge, is a notable subset of such efforts.

Collective Intelligence: The idea that the sum of the knowledge, capacity, or wisdom of a crowd of people is greater than that of any individual within that crowd, and can be tapped to improve decision-making and service delivery.

Data Collaboratives: A new form of collaboration, beyond the public-private partnership model, in which participants from different sectors—in particular companies—exchange their data to create public value.

Data Intelligence: Technologies and methodologies that use analysis or visualization of data to support decision-making processes.

Data Sovereignty: Data governance and management principle providing agency to individuals and particular groups in society in determining how data, especially personal data, is being collected and/or used.

Disruptive Innovation: Innovation that involves a fundamental shift in how tasks are completed, often with new entrants displacing incumbent businesses, industries, or service providers. In the context of this work, innovations that remove humans, but not always human tendencies or biases, from the equation.

Distributed Ledger Technology: A shared asset database that provides users with an identical copy of the same ledger, with updates to any of these distributed database nodes reflected in all versions of the database; blockchain is a notable example.[140]

Emerging Technology: 'Digitally stored information and the computation of it, whether by machines, organisations, people, or markets.'

Embodied Intelligence: "[T]he computational approach to the design and understanding of intelligent behavior in embodied and situated agents through the consideration of the strict coupling between the agent and its environment (situatedness), mediated by the constraints of the agent's own body, perceptual and motor system, and brain (embodiment)."[141] In this report, we use embodied intelligence to refer to the use of artificial intelligence in the physical world for the purposes of computer automation, deployment, and planning. It applies biological systems and human decision-making techniques to the computer learning process.

Ethical Fading: The failure to incorporate ethical requirements or features within machine learning algorithms.

139 See OECD. "Innovative Citizen Participation and New Democratic Institutions: Catching the Deliberative Wave." June 10, 2020. https://www.oecd.org/gov/innovative-citizen-participation-and-new-democratic-institutions-339306da-en.htm.

140 See The GovLab. "Blockchan.ge Primer: Glossary." Blockchange: Blockchain for Social Change. https://blockchan.ge/primer/glossary.html.

141 Cangelosi, Angelo, Josh Bongard, Martin H. Fischer, and Stefano Nolfi. "Embodied Intelligence." In Springer Handbook of Computational Intelligence, edited by Janusz Kacprzyk and Witold Pedrycz, 697–714. Springer Handbooks. Berlin, Heidelberg: Springer, 2015. https://doi.org/10.1007/978-3-662-43505-2_37.

Expert Models: An artificial system that attempts to mimic the decision-making of a human expert by following a set of predefined rules.

Internet of Things (IoT): Objects—whether they be wearable sensors, household appliances, or farming equipment—with embedded processors that communicate with one another via wireless telecommunications. IoT can include any object (including consumer devices) with the capacity to be connected to the internet and/or receive data.

Intelligence: In the context of this paper, insights generated from technology that, used separately or together, can improve how actors promote better governance and identify innovative solutions to pressing problems.

Machine Learning: Algorithms that can learn from and improve their performance through examples, data, and experience or iteration.

Open Data: Publicly available data that can be universally and readily accessed, used and redistributed free of charge. It is structured for usability and computability.

Open Innovation: A methodology that uses contests, challenges, and prizes to incentivize outside innovators to create novel approaches for addressing a shared problem.

Open Washing: Actions taken that give an institution the false appearance of openness, often in terms of open access to data or software, while retaining tight control over the purportedly open assets or processes.[142] Openwashing in the context of open data can also involve concealing unpalatable truths or a lack of transparency behind carefully selected data — sometimes referred to as "cherry-picking."

Robots: A reprogrammable, multifunctional machine that can perform a variety of tasks.

Smarter Crowdsourcing: A type of collective intelligence premised on the idea that while certain problems are well-suited for broad and open participation, others are better addressed through targeted engagement with individuals possessing relevant knowledge, experience, or expertise.

Sustainable Development Goals (SDGs): The SDGs are a set of 17 interlinked goals set by the United Nations General Assembly as a "blueprint to achieve a better and more sustainable future for all. They address the global challenges [...] including poverty, inequality, climate change, environmental degradation, peace and justice."[143]

Technological Appropriateness: Assessment of emerging technologies that involves a set of indicators such as potential for partnerships, social unsettling (disruptiveness), sustainability, and timeliness.

Technological Maturity: The position that emerging technologies naturally move through a hype cycle, similar to the Gartner Hype Cycle,144 that includes the following stages: nascent, inflating, deflating, maturing, mature.

Unmanned aerial vehicles: UAVs, also known as "drones," are aerial vehicles without a human pilot on board - often used when it may be less safe or convenient for an aircraft to be piloted. They can be fully or partially autonomous, though they are most often controlled by a remote pilot.

142 See https://openwashing.org

143 United Nations. "Take Action for the Sustainable Development Goals." United Nations Sustainable Development (blog). Accessed December 4, 2020. https://www.un.org/sustainabledevelopment/sustainable-development-goals/.

144 Gartner. "Hype Cycle Research Methodology." Accessed December 4, 2020. https://www.gartner.com/en/research/methodologies/gartner-hype-cycle.

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Publication Director Rémy Rioux
Editor-in-Chief Thomas Mélonio
Graphic design MeMo, Juliegilles, D. Cazeils
Design and production Luciole

Legal deposit 1st quarter 2021
ISSN 2680-7416
Printed by the AFD reprography service

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