UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

SUSTAINABLE DEVELOPMENT GOALS

STANDARDS & DIGITAL TRANSFORMATION

GOOD GOVERNANCE IN A DIGITAL AGE

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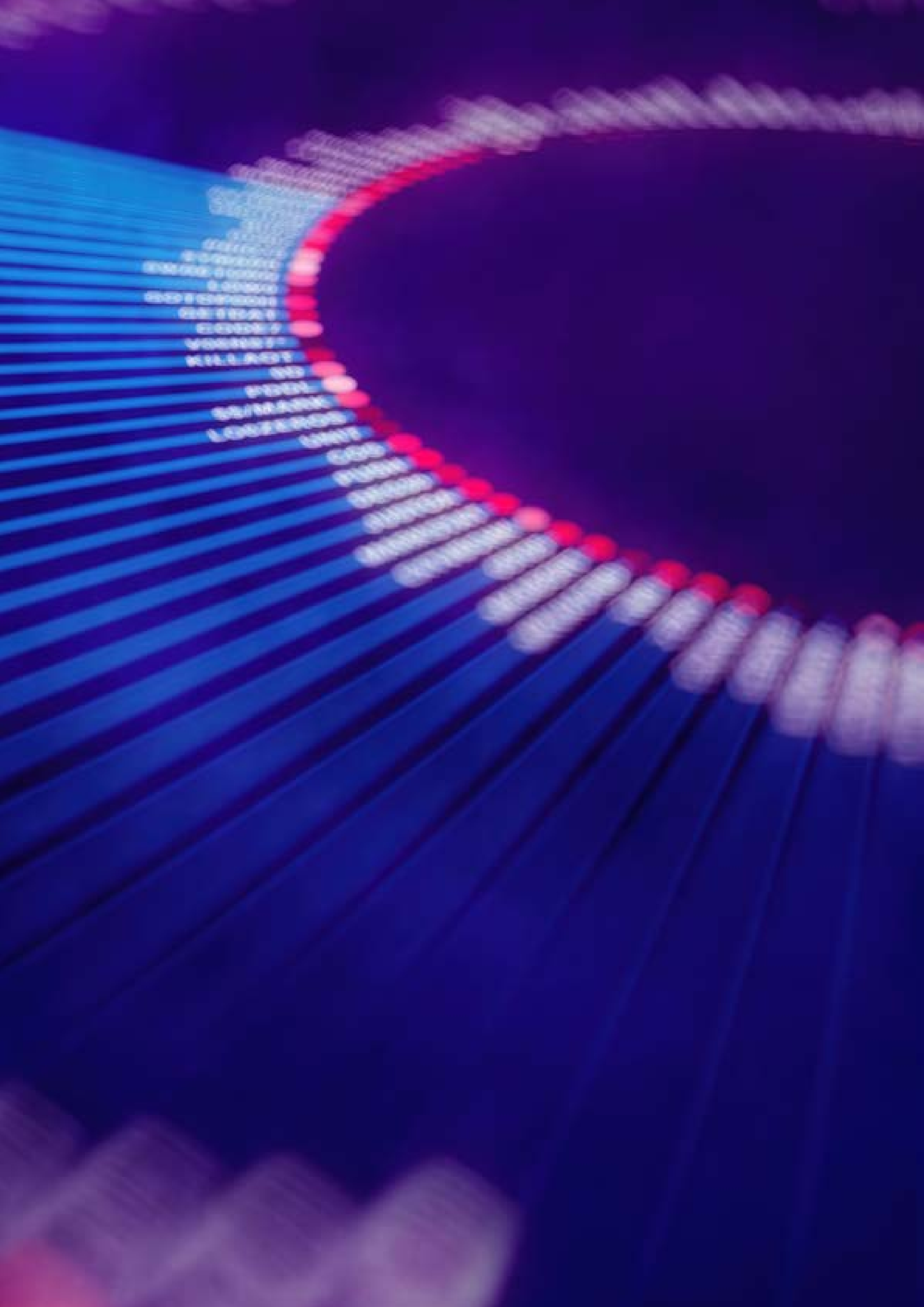

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DISCLAIMER

Foreword

Standards have an essential role in the digital transformation process, offering numerous benefits and opportunities for digital technologies to shape the future for the better. They can provide global, transnational, multidisciplinary and potentially rapid solutions to current and future technological and societal challenges derived from digital technologies as they set minimum requirements in terms of safety, security, reliability, efficiency, interoperability and trust.

For over 50 years, the United Nations Industrial Development Organization (UNIDO), the specialized United Nations agency mandated to promote inclusive and sustainable industrial development has supported the establishment and upgrading of standards and conformity assessment structures worldwide.

Developing economies can compete on global markets and participate in international value chains when they can demonstrate compliance with quality requirements and trade rules. With existing commercial opportunities, UNIDO is applying its expertise to support its developing member states to address these issues. It does this by working with governments to establish a Quality Infrastructure system, which covers the essential aspects of policy, institutions, service providers, and the value-added use of international standards and conformity assessment procedures.

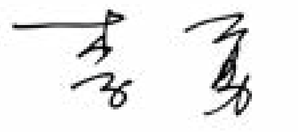
UNIDO is a strong proponent of the use of standards to support the achievement of the United Nations 2030 Agenda for Sustainable Development and Sustainable Development Goals (SDGs) through the enhancement of prosperity and the well-being of people, and for the preservation of the planet. To this end, UNIDO engages in all stages of the standardization process, from advocacy and pre-standardization; standardization; dissemination and implementation; to outreach and global partnerships.

Quality Infrastructure, and standards in particular will grow in importance and prominence as the global community continues to mobilize resources and efforts to respond to the Decade of Action that calls for the acceleration of sustainable solutions to address global social, economic and environmental challenges.

The ongoing digital transformation is being molded to support the three pillars of sustainability—people, planet and prosperity—in line with the SDGs for the benefit of society. The digitalization process provides possibilities to overcome the spatial and social barriers as digital technologies enables new inclusive and sustainable production methods and business models.

With inclusion and sustainability in mind, this publication serves to provide an overview of the digital transformation and the role of standards in digital transformation governance. It also calls the standard-setting community to act to help leverage the opportunities offered by digital technologies to contribute to the Decade of Action towards the achievement of the 2030 Agenda for Sustainable Development.

UNIDO is fully committed to doing its part to support standardization for digital technologies and continue its engagement with developing countries to achieve sustainability and prosperity for all.



LI Yong, UNIDO Director General

List of Abbreviations

4IR	Fourth Industrial Revolution
ADP	Advanced Digital Production
AI	Artificial Intelligence
AM	Additive Manufacturing
AMT	Additive Manufacturing Technology
ARSO	African Organisation for Standardisation
ASTM	American Society for Testing and Materials
CAA	Civil Aviation Authorities
CAD	Computer-aided Design
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CO_2	Carbon dioxide
COPANT	The Pan American Standards Commission
DLT	Distributed Ledger Technology
ETSI	European Telecommunications Standards Institute
EU	European Union
EUOS	European Union Observatory for ICT Standardisation
GDPR	General Data Protection Regulation
GPS	Global Positioning System
GQSP	Global Quality and Standards Programme
HMI	Human–machine Interface
IoT	Internet of Things
IIOT	Industrial Internet of Things
ICT	Information and Communication Technology
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IIC	Industrial Internet Consortium
IP	Intellectual Property
IPR	Intellectual Property Rights
ISO	International Organization for Standardization
ITU	International Telecommunication Union

JC	Joint Committee
JTC	Joint Technical Committee
ML	Machine Learning
NGO	Non-governmental Organization
NGGP	Namib Green Gold Processing (Pty) Ltd
NIST	National Institute of Standards and Technology
NSB	National Standards Body
NSO	National Standards Organization
OECD	Organization for Economic Cooperation and Development
OEE	Overall Equipment Effectiveness
PII	Personally Identifiable Information
PSDO	Partner Standards Development Organisation
QA	Quality Assurance
QI	Quality Infrastructure
QP	Quality Policy
QMS	Quality Management System
SA	Standards Association
SASAM	Support Action for Standardisation in Additive Manufacturing
SC	Sub Committee
SDGs	Sustainable Development Goals
SDO	Standards Development Organization
SSO	Standard Setting Organization
STEM	Science, technology, engineering and mathematics
TIPPSS	Trust, Identity, Privacy, Protection, Safety, Security
UAS	Unmanned Aircraft System
UAV	Unmanned Autonomous Vehicle
UN	United Nations
UNIDO	United Nations Industrial Development Organization
WEF	World Economic Forum
WHO	World Health Organization
WSN	Wireless Sensor Networks

Executive Summary

We are in the era of the Fourth Industrial Revolution (4IR), which is characterized by the convergence and complementarity of emerging technology domains, including nanotechnology, biotechnology, new materials and advanced digital production technologies. Despite the challenges posed by the disruptive nature of these innovations—which are increasingly connecting objects, machines, people and the environment—the digital transformation presents opportunities for inclusive and sustainable development.

This publication describes the digital transformation process and provides insights into its key drivers and the implications for sustainable development, particularly for the five dimensions addressed by the Sustainable Development Goals (SDGs)—people, prosperity, planet, peace (governance) and partnerships.

While revolutions and change have marked human development, what distinguishes the 4IR from previous industrial revolutions is the parallel technological breakthroughs within and across the digital, biological and physical spheres. The complexity and rapid pace of change of the 4IR also make the revolution distinctive. Moreover, the COVID-19 pandemic has been an unanticipated accelerator to the pace of change and structural shift towards the 4IR and the adoption of new technologies.

The SDGs sit at the heart of the 2030 Agenda for Sustainable Development and guide global, regional and national development endeavours until 2030. Their achievement will be significantly impacted by the rapid change brought about by digital transformation to production, the economy, the environment and society. The digital transformation is in full swing and although little mention is made to it or digital technologies in the 2030 Agenda,, it has the potential to be shaped to promote sustainability for the benefit of all parts of society.

Standards can play a crucial role in shaping the digital transformation process, offering benefits and opportunities for digital technologies, complementing regulations and contributing to digital transformation governance. In the context of digital transformation, the timely and harmonized adoption of standards can promote interoperability, productivity and innovation, and ensure the successful scale-up of solutions to be implemented globally.

Digital technologies and the new business models of digital transformation do not fit easily into the traditional regulatory framework regulators use to intervene in markets. Former modes of governance, which are largely reactive in nature, will prove to be ineffective in the era of advanced digital transformation. Governance rules and regulatory approaches for new technology and processes of innovation need to be more agile, flexible and resilient.

Even though the world has witnessed a rise of standard-setting activities related to digital technologies in recent years, it still falls short to meet the needs of producers, consumers and regulators and remains fragmentally concentrated at the national level, leaving room for international exploitation and harmonization.

A comprehensive review of the international landscape was undertaken for seven of the most-trending digital technologies of the 4IR, namely artificial intelligence and big data, blockchain/distributed ledger technology, Internet of Things, robotics, 3D printing and unmanned aircraft systems. While standardization reflects the different features and scope of impacts of 4IR technologies, this publication identifies the essential criteria to consider when developing standards for digital transformation worldwide.

The rapid and extensive adoption of digital technologies and their far-reaching pervasive impact on people, their prosperity and the planet also suggest a core set of distinct principles is needed to guide standards developed for digital transformation governance. These principles include trustworthiness, inclusiveness, sustainability, interoperability, safety and security, data privacy, and international collaboration.

In addition to these principles, unlocking the potential of standards to contribute to digital transformation governance requires standards developers to consider, inter alia, strategic planning, objectivity, creditability and transparency in their work. As this decade is critical for the planet and its people, this publication is a call to action to all stakeholders in the development of regulations and standards to consider the outlined principles in their work in order to leverage the opportunities offered by digital technologies and thereby contribute to sustainable development for the benefit of all people and the planet.

PART 1: **CONTEXT**

INTRODUCTION

The world is in the midst of the Fourth Industrial Revolution (4IR) powered by digital technologies that are transforming society, economies and the environment. These digital technologies are being integrated into all organizational areas, fundamentally changing how organizations operate and deliver value to customers or stakeholders—a process referred to as digital transformation. Increasingly connecting objects, machines, people and the environment, the disruptive nature of the technological innovations shaping the digital transformation makes it difficult to plan for and anticipate the future.[1] What is clear is that the seismic shift that the digital transformation brings has major implications for sustainable development.

Timely and harmonized standards can play a pivotal role in shaping the digital transformation process, complementing regulations and contributing to digital transformation governance. Standards can facilitate the ongoing digitalization of industry by promoting compatibility and interoperability between products and processes, while guaranteeing minimum levels of quality and safety. Furthermore, standards can serve as accelerators of change as they promote innovation and the uptake and quality of new digital technologies.

This publication describes digital transformation, its key drivers and the implications for three of the Sustainable Development Goal (SDG) pillars—people, prosperity and planet. It also highlights the role of standards in digital transformation governance (peace) as well as the importance of global collaboration (partnerships). A comprehensive review of the international standards landscape was undertaken for seven of the most-trending digital technologies of the 4IR, namely: artificial intelligence (AI) and big data, blockchain/distributed ledger technology (DLT), Internet of Things (IoT), robotics, 3D printing, and unmanned aircraft systems (UAS). While standardization reflects the different features and scope of impacts of 4IR technologies, this publication identifies the essential criteria to consider when developing standards for digital transformation worldwide. Based on the review, further consideration is given to what good governance principles are necessary for guiding the development of standards in the digital technology landscape to ensure that the technologies are human-centered and aligned to the goals of sustainability.

> Sustainable development seeks to meet the needs and aspirations of the present without compromising the ability to meet those of the future. Far from requiring the cessation of economic growth, it recognizes that the problems of poverty and underdevelopment cannot be solved unless we have a new era of growth in which developing countries play a large role and reap large benefits.

[1]The Enterprise Project 2021

CHANGING WORLD – THE FOURTH INDUSTRIAL REVOLUTION

Revolutions and change have marked human development. Agricultural societies were transformed by steam power in the first industrial revolution, beginning the movement of people from rural to urban settings. Steel, chemicals and electricity helped fuel mass production and accelerated urbanization in the second industrial revolution during the late 19th and early 20th centuries. Information technology saw the rise of the third industrial revolution in the latter half of the 20th century, characterized by digital electronics, computers, telecommunication and the Internet.

What distinguishes the Fourth Industrial Revolution (4IR) from previous industrial revolutions is the parallel technological breakthroughs within and across the digital, biological and physical spheres, with the process of convergence deepening as technologies continue to evolve. As highlighted by the World Economic Forum, "the unlimited possibilities presented by billions of people being connected by mobile devices will be multiplied by emerging technological breakthroughs in fields such as artificial intelligence, robotics, the Internet of Things, autonomous vehicles, 3-D printing, nanotechnology, biotechnology, materials science, energy storage, and quantum computing."

The complexity and exponential pace of change of the 4IR also make the revolution unique compared to previous industrial revolutions. Moreover, the COVID-19 pandemic has acted as an unanticipated accelerator to the pace of change and structural shift towards the 4IR and the adoption of new technologies.

The 4IR is still being shaped. The digital technologies[2] that sit at its heart will irrevocably transform systems and, consequently, how people live, work and play, therefore, societies need to understand both the rewards and risks of the 4IR as technological advancement occurs every day. It is essential to ensure the new technologies in the digital, biological and physical worlds remain human-centered and serve society and the planet as a whole for the prosperity of all. A new concept bounding the 4IR is Society 5.0, i.e. a people-oriented society that balances economic advancement with resolving social problems by a system that highly integrates cyberspace and physical space.[3] In Society 5.0, it is foreseen that "innovation will create new value that bypasses regional, age, gender, and language gaps and provides products and services finely tailored to diverse individual needs, some not yet known. Society can thus promote economic development and solve social problems."[4]

UNIDO's Investment and Technology Promotion Network expert panel on "Exploring the Future of Manufacturing and Industries: Industry 4.0's Potential in Advancing the Attainment of the SDGs and Shaping Society 5.0" shed further light on this topic. The panel discussion was part of the GMIS Digital Series of online webinar discussions on the 4IR, foreshadowing the GMIS 2020 Virtual Summit held in September 2021.

As previously referenced, the United Nations Sustainable Development Goals (SDGs) sit at the center of the 2030 Agenda for Sustainable Development and guide global, regional and national development endeavours until 2030. The 17 SDGs and 169 targets serve as an opportunity to tackle many of today's most pressing world issues. They are universal, integrated and indivisible, and seek to balance the economic, social and environmental dimensions of sustainable development. Subsequently, as the 4IR continues to reshape the world, alignment with the SDGs is fundamental to ensure that benefits accrue for people, delivering them prosperity, and that the planet is protected.

[2] Terms found in the literature and used for digital technology include: new technology, 4IR technology, frontier technology, emerging technology, disruptive technology, future technology and transformational technology. This publication makes use of these terms inter-changeably.

[3] https://www8.cao.go.jp/cstp/english/society5_0/index.html

[4] Nature-like and Convergent Technologies Driving the Fourth Industrial Revolution, UNIDO, 2019

IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

The 4IR is in full swing and already has global implications for sustainable development. Enormous opportunities arise from the new and transformational technologies as they enable new modes of production, new businesses and societal models and new behaviours that can disrupt established and fundamental paradigms. **Strong global partnerships (Goal 17) between multiple stakeholders are needed to ensure sustainability is incorporated into digital technologies and the 4IR.**

The examples that follow provide a general context of the potential the 4IR has to contribute to the SDGs at different levels.

The implications of the 4IR for people are extensive and can contribute to ending poverty (Goal 1). Equitable access to and gender-responsive and gender-specific design of new technologies is needed to reduce inequality and promote gender equality (Goal 5). To foster peaceful, just and inclusive societies, the benefits of the 4IR need to be equitably distributed (Goal 16). However, unless actively addressed, the lack of digital connectivity and access to technologies promoting digital literacy will increase disparities between countries, societies and individuals, with the poorest and women and children suffering the most. Education and the health sector increasingly utilized digital technologies during the COVID-19 pandemic, which should be sustained. As evidenced by the least connected in society having suffered as access to education resources was restricted and health services having struggled due to reaching operational capacities, achieving accessible quality education (Goal 4) and promoting health and well-being for all (Goal 3) depends on developing an open and accessible digital technology infrastructure. New technologies deployed in agriculture can help increase productivity, improve resource efficiency and build resilient food supply chains, and therefore, have a role to play in delivering Goal 2, zero hunger.

The 4IR has positive implications for prosperity as digital technologies transform economic growth and can reduce inequalities within and between countries (Goal 10). Production transformation by advances in robotics, IoT, machine learning, AI and big data will change the workplace and alter jobs for people, potentially eliminating them or reducing their scope, challenging Goal 8. The integration of information and communications technologies (ICTs) within every part of the production process is the current and evolving interconnected realm of smart manufacturing. Agile, adaptive and intelligent manufacturing processes that combine the digital and physical in the complete value chain will produce products more rapidly, helping to advance enduring industrialization (Goal 9), and efficiently use fewer resources, stimulating responsible, sustainable production and consumption (Goal 12).

The advancement in economic growth delivered by new production methods should be aligned with full, productive and decent employment (Goal 8). Smart cities and infrastructure will become both more resilient and sustainable as digital technologies help deliver sustainable cities (Goal 11) and infrastructure (Goal 9), and reduce resource consumption. Goal 10, the reduction in inequality, depends on the equal distribution of benefits promised by the new technologies of the 4IR. However, the 4IR technologies are not without risks, for example, the potential to monitor and survey citizens, via AI face recognition technology, raises privacy and human rights issues.

The 4IR also presents environmental challenges and opportunities. Successive industrial revolutions and human activity use the earth for its resources and to deposit waste. Deployment of integrated new technologies can replace unsustainable behaviours, business models and industrial activities, contributing to sustainable energy (Goal 7), and help combat climate change (Goal 13). However, digital technologies are not without environmental impacts, for example, high energy consumption of ICT systems and the burgeoning waste disposal problem resulting from consumer electronic equipment. 4IR technologies can disrupt the traditional linear economic model (make, use and dispose) to a

DIAGRAM 1 – IMPLICATIONS OF THE 4IR FOR SUSTAINABLE DEVELOPMENT LINKED TO SPECIFIC SDGS

PEOPLE

The extensive implications of the 4IR for people can contribute to improving livelihoods and ending poverty

1 NO POVERTY

Gender-responsive and gender-specific design of (and equitable access to) new technologies is needed to reduce inequality and promote gender equality

5 GENDER EQUALITY

New technologies deployed in agriculture can increase productivity, improve resource efficiency and build resilient food supply chains

2 ZERO HUNGER

Achieving accessible quality education and promoting health and well-being for all depends on developing an open and accessible digital technology infrastructure

3 GOOD HEALTH AND WELL-BEING

4 QUALITY EDUCATION

Digital technologies can address water scarcity, sanitation and water quality

6 CLEAN WATER AND SANITATION

To foster peaceful, just and inclusive societies, the benefits of the 4IR need to be equitably distributed

16 PEACE, JUSTICE AND STRONG INSTITUTIONS

The transnational nature of many disruptive technologies calls for greater international partnerships and consensus to build effective regulations and policies

17 PARTNERSHIPS FOR THE GOALS

PLANET

New technologies can support a circular economy, increasing sustainable economic growth and the protection of marine and terrestrial ecosystems

Deployment of new technologies can promote sustainable practices, business models and industrial activities, thereby combating climate change

New technologies increase resource efficiency, stimulating responsible, sustainable production and consumption

Smart cities and infrastructure will become more resilient and sustainable as digital technologies help deliver sustainable cities

Deployment of new technologies can alter unsustainable behaviors, business models and industrial activities, contributing to sustainable energy production

PROSPERITY

The 4IR has positive implications for prosperity as digital technologies transform economic growth and can reduce inequalities within and between countries

Agile, adaptive and intelligent manufacturing processes that combine the digital and physical spheres across the entire value chain will increase productivity, helping to advance enduring industrialization

Advances in robotics, IoT, machine learning, AI and big data will transform production, altering the workplace and jobs for people

circular economy. An economy regenerative by intention and design seeks to replace the end-of-life concept with restoration and reuse aimed at sustainable economic growth and the protection of marine and terrestrial ecosystems (Goals 14 and 15).

The pace and the complexity of the 4IR can blur international borders and entangle boundaries between public and private, presenting national regulators with unique governance challenges. **Regulation can struggle to keep up with advances of the 4IR, hindering innovation and leaving society with outdated laws and regulations.** Regulators need to adopt a more agile, flexible approach to regulation to seize the potential of the 4IR to deliver benefits to society and manage its risks. In this vein, the G20 Digital Economy Task Force has been piloting an initiative on agile regulation for 4IR among several countries, serving as a useful tool to share experiences and common approaches to more agile governance and regulatory models for innovation.

To grasp the opportunities and mitigate the risks from 4IR technology, the 'regulate and forget' approach needs to give way to an 'adapt and learn' approach. The pandemic illustrated that regulation was outpaced by technology and reinforced the need for speed with fast-track regulation being developed to facilitate medical innovations, such as telemedicine. The transnational nature of many disruptive technologies calls for greater collaboration between national regulators and stronger international partnerships and consensus to build effective regulations and policies. Noting that good regulation is essential for economies to function efficiently, while meeting important social and environmental goals, the OECD Recommendation of the Council on Regulatory Policy and Governance is the fruit of careful assessments of best practice identified by the Regulatory Policy Committee through a decade of reviews of OECD countries. Representing a maturing of thinking and learning from experience in this complex policy area, the Recommendation develops a systemic governance framework that can deliver ongoing improvements to the quality of regulations. It provides governments with advice on the development of institutions and the application of regulatory management tools. It also provides practical measures or benchmarks against which countries can assess their capacity to develop and implement quality regulation.

As a voluntary complement to regulations, standards have a unique role to play in digital transformation governance. **Standards offer global, transnational, multidisciplinary and potentially rapid responses to the needs of the 4IR's technological developments.** Stakeholders, if fully engaged, are well placed to ensure standards for disruptive technologies that are reshaping businesses and societies worldwide are synchronized with the needs of people, serving everyone in society and sustainable development. Standards, therefore, must play a crucial role in harnessing digital transformation equitably.

DIGITALIZATION AND THE DIGITAL TRANSFORMATION

The Fourth Industrial Revolution (4IR) is a term coined in 2016 by Klaus Schwab, Founder and Executive Chairman of the World Economic Forum (WEF). It is characterized by the convergence and complementarity of emerging technology domains, including nanotechnology, biotechnology, new materials and advanced digital production (ADP) technologies. The latter includes 3D printing, human–machine interfaces and AI, and is already transforming the global industrial landscape. Incorporating ADP technologies into industrial production processes has given rise to the concept of Industry 4.0, also known as the Smart Factory—one that learns as it works, continuously adapting and optimizing its own processes accordingly.

The 4IR is also characterized by the widespread and ever-increasing phenomena of *digitization*, i.e. the conversion of analogue information into digital form. At the same time, the ever-greater *digitalization*—the development and application of digital and digitalized technologies that augment and dovetail with all other technologies and methods[5]—is serving to reinforce and expand the *digital economy* (Text Box 1).[6]

Text Box 1 – The Digital Economy

The OECD defines digital economy as incorporating all economic activity reliant on or significantly enhanced by digital inputs, including digital technologies, digital infrastructure, digital services and data. It refers to all producers and consumers, including the government, utilising these digital inputs in their economic activities.

In a larger context, digital transformation is a broader term than digitalization. It is the integration of digital technology into all organizational areas, fundamentally changing how the organization operates and delivers value to customers or stakeholders.[7] It is also about prioritizing organizational culture change, which requires organizations to continually challenge the status quo, experiment and get comfortable with failure. Digital transformation is a widely used term that, in practice, will look very different in each organization. In essence, it refers to the customer-driven strategic business transformation requiring organizational change and the implementation of digital technologies.

Three factors are driving the digital transformation. The first driver for digital transformation is necessity. Survival and adaptation to rapidly changing markets and circumstances challenge organizations to rethink how they execute their operations radically. The dramatic global impact of the COVID-19 pandemic advanced the adoption of digital technologies. It prompted more organizations, both commercial and governmental, to engage with digital transformation necessitated by stresses such as supply chain disruptions, time to market pressures and rapidly changing needs in the health sector.

The second reason why digital transformation is happening is the technology itself. According to the OECD, mobility, cloud computing, IoT, AI and big data analytics are among the most important technological drivers. The opportunities offered by digital technologies for innovation and efficiency drive change powered by rapid connectivity, exponential generation of data and affordability as time passes. Governments, for example, rolled out many large-scale digital innovations at speed during the pandemic, such as deploying AI and automation tools to deliver faster services and reduce workloads and the shift to the cloud, allowing employees to work remotely and helping governments reach citizens. Scaling digital infrastructure, creating a more digitally savvy workforce and investing in citizen connectivity are achievable goals for governments with digitalization.

Expectations have been raised by digitalization and this heightened set of expectations is the third factor driving digital transformation. Citizens count on the same kind of experience in a professional setting as they experience with technology in their personal lives. Delivery of services and products that meet or go beyond stakeholder expectations for seamless integrated and efficient customer experience that meet their demands require businesses, governments and all organizations to transform their delivery models, embracing digital technologies and innovative approaches.

[5] WBGU EU Policy paper on digitalisation
[6] OECD Roadmap Towards a Common Framework for Measuring the Digital Economy 2020
[7] The Enterprise Project 2021

DIGITAL TRANSFORMATION IMPACTS ON PEOPLE, PROSPERITY AND THE PLANET

The accelerated pace of change brought about by digital transformation to production, the economy, the environment and society will significantly impact the achievement of the 2030 Agenda for Sustainable Development and related SDGs. The digital transformation is in full swing and although little mention is made to it or digital technologies in the 2030 Agenda for Sustainable Development, it will have profound consequences for people, their prosperity and the planet. As it is a development driven by humans, it has the potential to be shaped to promote sustainability for the benefit of all parts of society.

Implications for planet

Unchecked digital transformation unaligned with the environmental constraints of the earth will negatively impact the **planet**, increasing resource and energy consumption, exacerbating damage to terrestrial and water ecosystems and accelerating climate change. Digital technologies offer the potential to contribute to the protection of the planet. Digitalization could transform energy and transport into low-carbon systems. Digital infrastructure technology could deliver smart cities, homes and roads that minimize resource consumption and waste whilst offering more sustainable communities. Digital technologies can address water scarcity, sanitation and water quality through sensors and IoT, as well as improve sustainability in fisheries. If businesses harness the innovative possibilities of digital transformation, they could achieve circular economy and dematerialization opportunities. However, any benefits to sustainability goals require sustainability concepts to be a fundamental part of the digital transformation.

DIAGRAM 2 – DIGITAL TRANSFORMATION **IMPACTS**

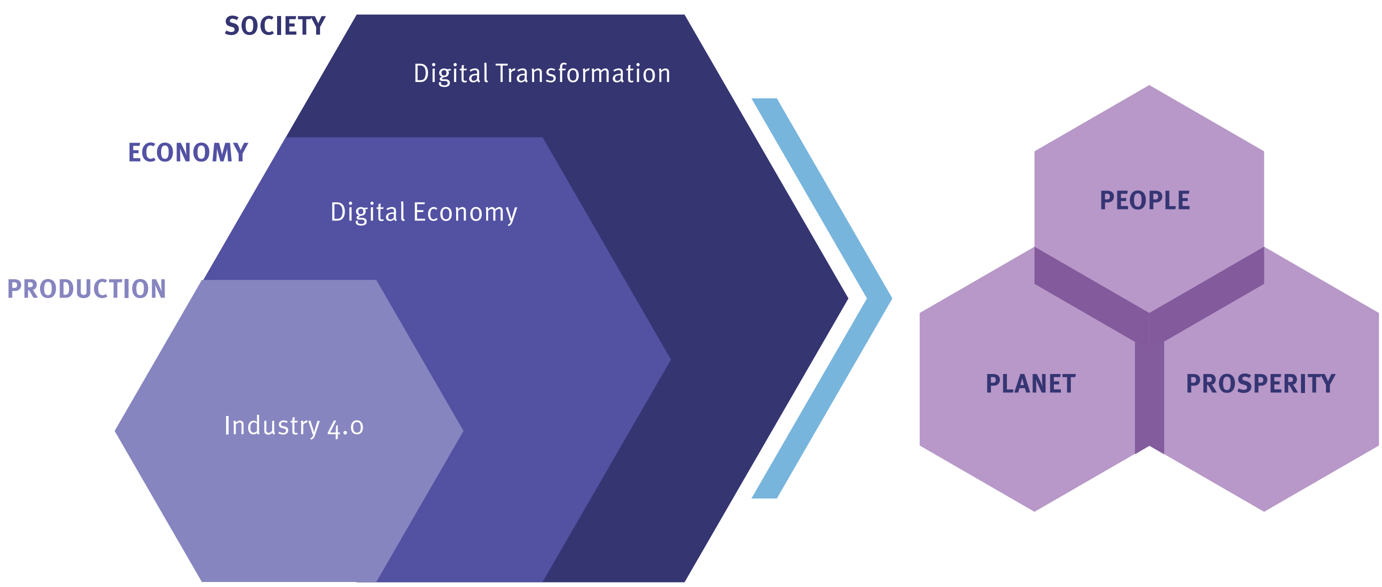
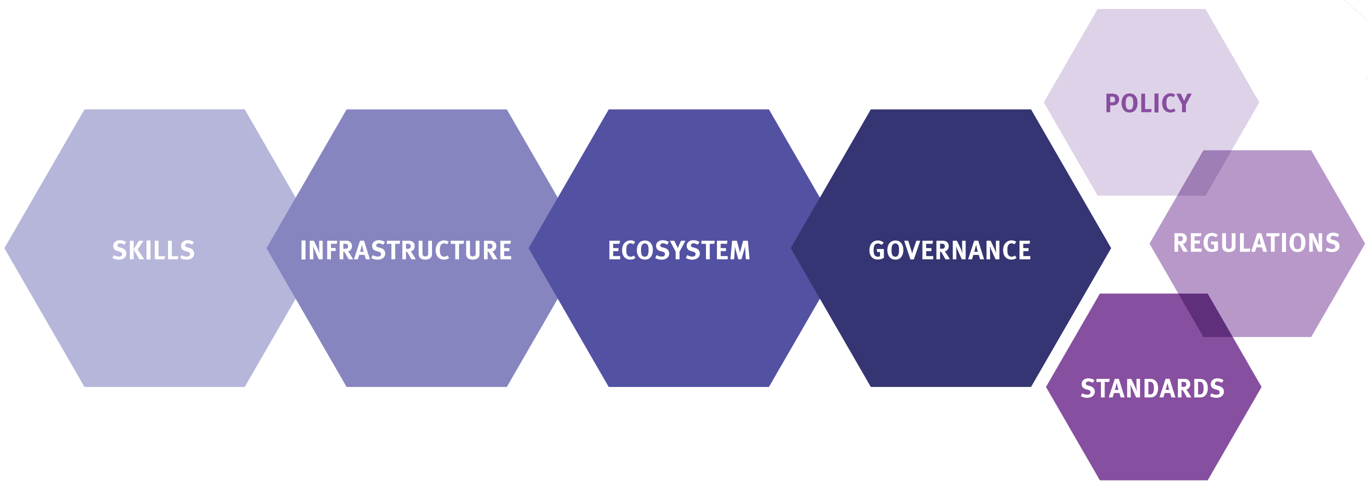


DIAGRAM 3 – DIGITAL TRANSFORMATION **ENABLERS**



Implications for people

Digitalization is unevenly distributed but offers the potential for overcoming spatial and social barriers to benefit people. Developing and emerging economies are poorly served by digital technologies, and their people, especially the poorest, are excluded from the opportunities and benefits. Poverty excludes participation in the digital economy and marginalizes vulnerable groups, especially women, children, migrants and rural dwellers who are further disadvantaged by lack of access to communication technologies. Around two billion people worldwide lack access to ICT, including access to the knowledge, education, and training needed for economic inclusion in the digital economy. The digital transformation is disrupting the employment landscape. New forms of employment are being created and global networks mean geographic location is less of a barrier to people working remotely in the digital economy. Science, technology, engineering and mathematics (STEM) skills are in demand, highly valued and rewarded, whereas other non-digital occupations such as child care remain undervalued. Limited education resources to increase STEM skills further weaken participation in the digital economy. Social and labour standards risk being undermined and jobs replaced by digital technologies deployed in smart manufacturing, agriculture and commerce. People are more interconnected and dependent on digital infrastructure that exposes them to cybersecurity threats such as privacy breaches, technical failures and unintended consequences of the new technology like gender and ethnic bias in AI.

Implications for prosperity

Digital transformation is fundamentally changing the commercial world, impacting competition whilst disrupting markets and affecting prosperity. Digital technologies are transforming production by enabling new production methods and business models. For example, smart manufacturing harnesses agile, adaptive and intelligent processes to combine the digital and physical spheres to produce more efficiently with greater returns, using fewer resources. The global market for digital transformation technologies and services was valued at USD 1.3 trillion in 2020.[8] However, the digital economy has created vast monopolies dominating sectors of society with little accountability or transparency. Digitalization has allowed data collection and monitoring systems, on a scale previously not seen, for use by a variety of actors that infringe on privacy and personal rights and freedoms. New and emerging technologies need to remain human-centered and serve society to ensure everyone has equitable access to benefit from the economic and social opportunities.

Ensuring digital transformation enablers are in place is integral to supporting the adoption and implementation of digital technologies and for people and the planet to prosper from technological change.

[8] IDC Market Report

PART 2: STANDARDS

The World Trade Organization's Agreement on Technical Barriers to Trade (WTO/TBT) defines a standard as a voluntary document to which compliance is not mandatory, as opposed to a technical regulation, to which compliance is mandatory. The WTO/TBT definition has introduced a clear-cut distinction between standards (voluntary) and technical regulations (mandatory), which is useful and has been broadly accepted in the field.

Standardization of digital technologies happen in the national, regional and international space in various organizations, including companies, professional bodies and trade associations, non-governmental organizations (NGOs), intergovernmental organizations and standards development organizations (SDOs).

At a regional level, SDOs are undertaking the analysis of the standards landscape in individual digital technologies, for example, the road map analysis from the European Committee for Standardisation and European Committee for Electrotechnical Standardisations (CEN-CENELEC) Focus Group on AI and European Union Observatory for ICT Standardisation (EUOS) global landscape analysis of AI standards. Coordination between international SDOs should be pursued to prevent duplication of work and harness the collective expertise and stakeholder engagement of these organizations.

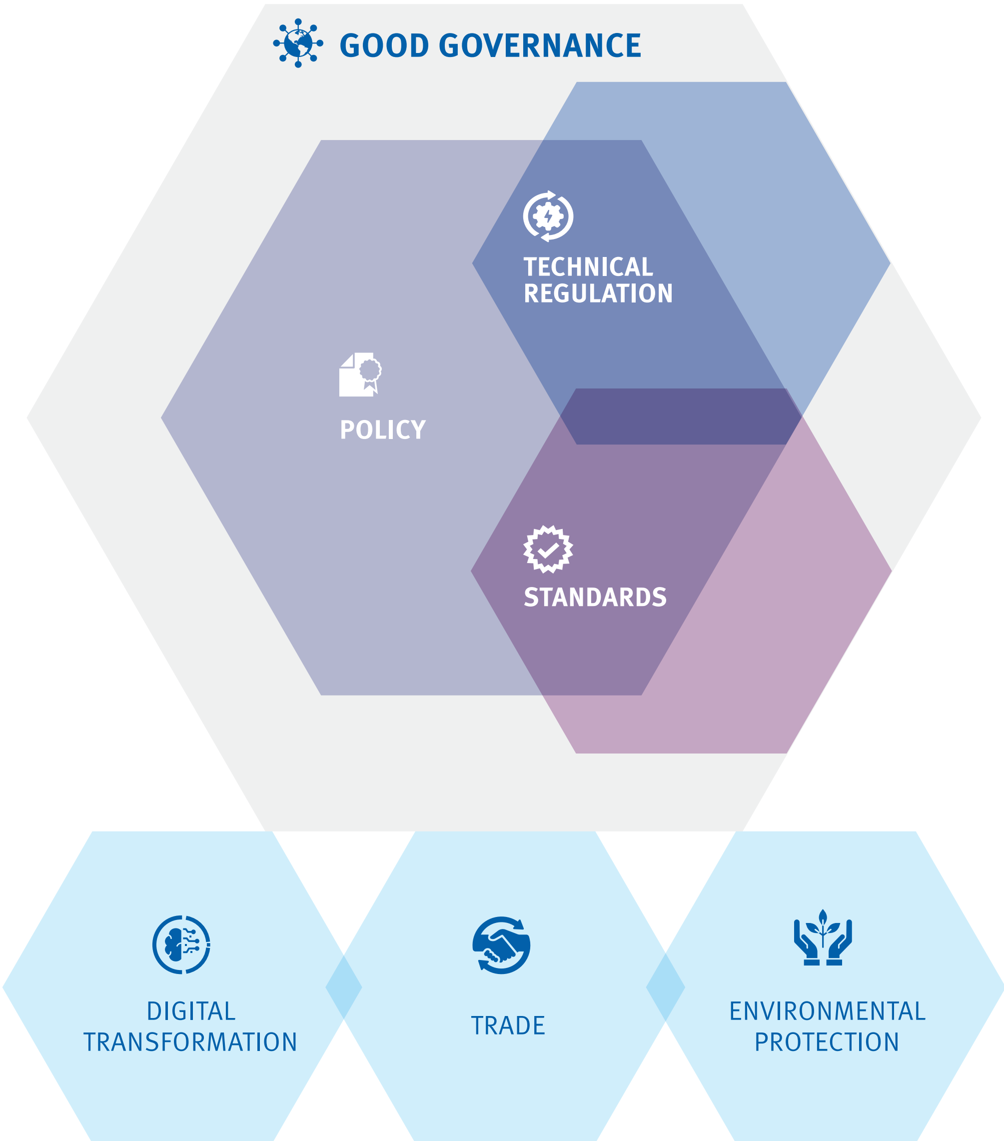
THE ROLE OF STANDARDS IN ECONOMIC GOVERNANCE

The role of standards in economic governance derives from the wide range of functions that they fulfil. Amongst others, standards define interoperability between products and processes, transfer information both between economic agents and between machines and systems, and guarantee minimum levels of quality and safety for consumers. These functions, in turn, affect the economy in a variety of ways, including through the improvement of competition and efficiency, the exploitation of network effects, the diffusion of innovation and the reduction of production costs. Besides interoperability of new and legacy technologies, in general there is also a horizontal dimension of interoperability of technologies, products, services and systems produced by different organizations at sectoral, national, regional and international levels. Interoperability enables the capability to communicate, execute programmes, or transfer data among these various functional components.

There is also a circular relationship between standards, regulations and policies, which feed into an overall concept/public good of good governance. Standards are a voluntary complement to regulation, which have the effect of enhancing efficiency and productivity. These standards inform effective regulations, which can create an enabling environment for innovation and minimize risk for disruptors and investors. The WTO/TBT acknowledges the role of technical regulations, standards, and conformity assessment procedures, e.g. testing, inspection and certification, for the efficient attainment of public goals, and sets rules to ensure that these measures are prepared, adopted and applied in ways that do not create unnecessary barriers to international trade. Although the TBT Agreement is primarily about technical regulations, standards (which are voluntary by definition in the TBT Agreement) have an important role in the framework of the agreement. WTO's members are expected to use international standards (whenever they exist, or their completion is imminent) as a basis for technical regulations—and technical regulations in accordance with relevant international standards are not deemed to constitute an unnecessary obstacle to trade. The TBT Agreement requires that its members use relevant international standards, guides or recommendations for conformity assessment procedures as a basis for their own procedures for a positive assurance of compliance with technical regulations and standards. Standards developed by international organizations can, therefore, provide an effective response to market barriers.

In the context of digital transformation, the timely and harmonized adoption of standards is likely to play a key role to this end, both as a means of promoting interoperability, productivity and innovation, and of ensuring the successful scale-up of solutions to be implemented globally. Standardization can offer a number of benefits and opportunities for digital technologies, inter alia: unifying technologies and specifying common technical features; promoting interoperability and compatibility; helping to eliminate technological silos; enhancing innovation and growth; accelerating technology adoption; building trustworthiness and describing governance frameworks; aiding user understanding, acceptance and confidence in new technologies; helping to minimize risks, improving safety, avoiding technological lock-ins and validating quality; collating best practices and use cases; and supporting policy and legislation.

These outcomes may be especially beneficial in restoring international manufacturing and trade to their previous vitality, as both sectors slumped significantly due to the COVID-19 pandemic, the associated lockdowns and value chain breakdowns in many regions. The COVID-19 pandemic has become a catalyst to accelerate digital transformation for which a set of internationally recognized standards—urgently needed by policymakers, businesses, and the public—are indispensable as latent risks in all industries have been crucially revealed. Such risks include weak and untimely governance, the inefficiency of the global value chain, and the lack of knowledge, awareness and trust of the public. Commonly accepted standards will enhance the smooth operation of global value chains, enhancing confidence in quality, traceability and safety across borders, while also contributing to industrial recovery and resilience.



THE ROLE OF STANDARDS IN GOOD GOVERNANCE OF DIGITAL TRANSFORMATION

Digital technologies and the new business models of digital transformation (as previously outlined with respect to agile regulation) do not fit easily into the traditional regulatory framework regulators use to intervene in markets. It is clear that previous modes of governance, which are largely reactive in nature, cannot hope to be effective in the era of advanced digital transformation. Governance rules and regulatory approaches for new technology and processes of innovation need to be more agile, flexible and resilient through the development of experimental regulation such as regulatory sandboxes, anticipatory approaches, multi-stakeholder use of guidelines and standards, and the promotion of international initiatives. Furthermore, regulators, as stakeholders, need to be involved in the development of voluntary standards, e.g. participate in national standards body (NSB) technical committees, to ensure that the standards are suitable if they choose to refer to them in regulations.

The widespread recognition of a need for proactive regulation has led to some innovative developments in recent years concerning how we "square the circle" of developing timely standards and regulations for advanced technologies, without hindering innovation or leaving regulatory voids, in which little is done to mitigate the potential downside effects of unchecked digital transformation. This has begotten the concept of "agile regulation", which has appeared prominently in multilateral discourse on digital transformation in recent years. For instance, the concept of regulatory sandboxes first emerged in the United Kingdom in 2016, primarily in the fintech sector. This concept essentially allows for testing of innovative concepts in a controlled environment under the supervision of regulators, in order to facilitate innovation without encumbering innovators with overly-burdensome regulations in the initial stages of development.

Other forms of agile regulation include policy prototyping, in which new innovations are subjected to small-scale testing prior to scale-up; and technology foresight, which inputs for the formulation of technology policies and strategies that guide the development of the technological infrastructure. Such approaches have become very popular in recent years, with the World Bank reporting that 57 countries have implemented the concept of agile regulation to some extent.[9]

However, as innovative as the agile regulation concept is, it cannot meet all governance needs for digital transformation in a vastly heterogeneous international order, bearing very different capacities, needs and priorities. Least developed countries typically have very different capacities and needs than high-income countries with respect to digital transformation. The UNIDO Industrial Development Report 2020 found that just ten economies (mostly in the Global North) account for over 90% of advanced innovation patents and 70% of associated exports, while 88 developing countries play little meaningful role in the advanced digital production sector, either as consumers or producers. This indicates a vast digital divide which cannot be solved by piecemeal or ad hoc solutions. In light of this, developing countries are increasingly participating in the development of international standards, i.e. in the ISO and IEC systems. This is to such an extent that initiatives such as the Commonwealth Standards Network and the Belt and Road Initiative and other capacity building projects are seeking to mobilize developing countries in standards development.

Standards must, therefore, play a foundational role in any initiative to harness digital transformation equitably on a global basis. Standards are voluntary rules or guidelines that codify information. They provide specifications and technical information (intended for common use) on products, materials, services and processes. They are particularly relevant to technology-related products. Standards are not developed in isolation but are produced in a regulatory and policy framework, a framework evolving to encompass the challenges presented by digital transformation and the digital technologies, which also needs to account for challenges posed to sustainability.

Standards have an essential role in providing solutions to current and future technological and societal challenges derived from digital technologies because they set minimum requirements in terms of safety, security, reliability, efficiency, interoperability and trust. They also act as a precursor to regulations on a voluntary basis, granting expertise and buy-in from private sector innovators, and leading to regulations that minimize risk and create an enabling environment for innovators and investors. Consequently, several international organizations and professional bodies have developed considerable policy expertise regarding digital standards in recent years, not least the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the International Telecommunication Union (ITU), the United Nations Industrial Development Organization (UNIDO), the Institute of Electrical and Electronics Engineers (IEEE) and the G20.

Transnational blurring also serves as an opportunity for international organizations to fill the void of global leadership and contribute to the well-being of all humankind from a holistic perspective instead of a self-focused one at the national level. International organizations remain impartial in developing, implementing, and monitoring standards by engaging countries to be a standard-setter rather than simply a standard-taker to achieve a shared prosperous future. International organizations launch multiple voluntary initiatives, such as the United Nations Global Compact and the Global Manufacturing and Industrialisation Summit (GMIS) led by UNIDO, to involve all stakeholders, especially the private sector.

However, a preponderance of standards may also bring some challenges in terms of over-complexity and potential monopolies or abuse of a dominant market position by larger technology providers. It is thus vital to ensure collaborative processes/multi-stakeholder partnerships for the development of necessary standards and to strike the correct balance in this regard.

[9] https://blogs.worldbank.org/psd/four-years-and-counting-what-weve-learned-regulatory-sandboxes

ESSENTIAL CRITERIA FOR DEVELOPING STANDARDS FOR DIGITAL TRANSFORMATION

Standards can also be seen has having enabled digital transformation by codifying best practice and enabling technology transfer. Activities concerning the development of standards at the international level were comprehensively reviewed for the purpose of this publication to include the following categories: **foundational/general**, describing the technology's vocabulary, definitions, and taxonomies; **method and approaches/operation**, containing the characteristics of the technology in operation and special features of its operation and also including approaches, engineering aspects, interoperability, testing, health and safety, risk assessment, data, materials and quality and security; **trustworthiness**, covering such fields as governance, privacy, transparency, ethics, accountability, and cybersecurity; and **use cases/application,** referring to a selection of case studies and how these might inform best practice on applying seven of the most-trending digital technologies of the 4IR (such an approach has already been adopted by international fora in other contexts, e.g. the G20's Compendium on the Use of Digital Tools for Public Sector Continuity).

Not all categories apply neatly to each of the seven digital technologies. Each of the seven technologies has foundational or general standards, and the category of method and approach/operation is also relevant to all seven technologies.

As not all digital technologies have the same impacts on people and society, standardization efforts in trustworthiness are concentrated in AI and big data, DLT/blockchain and IoT. These technologies have the biggest potential impacts on people in terms of infringement on human rights and privacy and their societies than, for instance, 3D printing and unmanned aircraft systems (UAS). For example, standards on UAS cover the safety aspects of shared airspace and it is national civil aviation regulations and data protection laws that govern privacy aspects of civil drone operation in the EU.

These four criteria are essential to developing our understanding of what to consider when developing standards for digital transformation worldwide, and for seven of the most-trending technologies in particular, which will be further discussed in part three of this publication.

PART 3: **TECHNOLOGIES**

THE BIG 7 DIGITAL TECHNOLOGIES OF THE 4IR DESCRIBED

The digital transformation is powered by digital technologies of the 4IR. The rapid adoption of these disruptive technologies is accelerating and has been further boosted by the COVID-19 pandemic. Global spending on digital transformation technologies and services grew by 10.4% in 2020 to USD 1.3 trillion.[10]

Technological adoption is not a geographically even process; a greater quantity and rapidity of technology adoption is happening in developed countries. Least developed countries (LDCs) are hampered by, among other things, lack of ICT and access to proper architecture and basic assets such as computers and smart devices but most importantly, the capacity to ensure people have the right set of basic skills. Illustrating this unevenness: in 2019, 92% of Swiss households compared to 38% of Bangladeshi, 36% of Peruvian and 34% of Pakistani households had access to ICT.[11]

Seven digital technologies of the 4IR that will considerably impact people, their prosperity and the planet include: artificial intelligence (AI) and big data,[12] blockchain/distributed ledger technology (DLT), Internet of Things (IoT), robotics, 3D printing and unmanned aircraft systems (UAS). **While the scope and impact of digital technologies vary, standardization has a role to play in each one to help deliver trust, privacy, protection, interoperability and sustainability.** A comprehensive review was undertaken for the purpose of this publication of the current developed digital-related standards and SDO committee activities in the digital space, with emphasis on the seven big digital technologies of the 4IR. These seven digital technologies and the role of standards for each will further be discussed below.

ARTIFICIAL INTELLIGENCE (AI) AND BIG DATA

About the technology

There are many and varying definitions of artificial intelligence (AI). Since it was first defined in the 1950s, defining AI has been driven by different categorizations mainly based on how the AI system thinks or acts, however, still today there is no straightforward definition. The UNIDO Industrial Development Report 2020 conceptualized it as, "...the branch of computer science seeking to simulate the human capacity to reason and make decisions. The term usually refers to such artificial intelligence techniques as machine learning, deep learning, neural networks, fuzzy logic, computer vision, natural language processing and self-organizing maps to provide machines and systems with human-like cognitive capabilities, such as learning, adapting, perceiving and solving problems. Artificial intelligence can be defined as making computers intelligent and capable of mimicking and predicting human behaviour and solving problems as well as or better than humans."

AI is a field that is growing exponentially, full of innovators and disruptors, and draws on the power of big data; consequently, these two technologies are considered together. Every two days more data is produced than in all of history before 2003 and the pace is increasing.[13] This surge in data generation has led to big data analytics and, along with the all-pervading ICT, has helped drive AI adoption. AI is making rapid inroads into domains previously the preserve of humans, potentially offering solutions to some of the biggest challenges facing the planet and its people. However, AI also presents risks that governments, society and businesses need to understand and tackle to ensure AI systems reach their intended functional goals, benefitting people and the planet, while avoiding unintended consequences.

Measuring the development of AI technologies is challenging as the boundaries between AI and other technologies blur and change over time; for example, AI is present in physical technology like driverless cars and care robots and software systems, like medical diagnostic tools and chatbots. The number of patent applications published by more than 100 patenting authorities in the AI field grew by an average of 28% a year between 2012 and 2017.[14] Japan, Republic of Korea and the United States accounted for over 60% of AI-related patent applications from 2014 to 2016.[15] The global value of the AI market size was USD 62.35 billion in 2020 with an anticipated compound annual growth rate of 40.2% from 2021 to 2028.[16]

Role of standards for AI and big data

Developing norms and standards is a big task in the AI and big data fields. SDOs have entered robustly into the field, and at the moment technical standardization work is being actively pursued by international SDOs including ISO, IEC, ETSI, ITU-T and IEEE. National standards bodies (NSBs) have also entered enthusiastically into the field, in particular in China, the United Kingdom and the United States. The comprehensive review of standards at the international level identified standard making in AI and big data occurs in the following categories:

- Foundational
  - Vocabulary AI and data
  - Taxonomies
- Methods and approaches:
  - Computational approaches
  - Architectures and engineering of AI systems and data
  - Characteristics of AI systems
  - Quality and data for AI

[10] IDC Market Report
[11] ITU Digital Development Dashboard
[12] For the purpose of this publication, AI and big data have been grouped together.
[13] David Stuart, Facilitating Access to the Web of Data
[14] *The IP behind the AI boom,* WIPO Magazine
[15] WIPO Technology Trends 2019 Artificial Intelligence
[16] Grand View Research Market Analysis Report

» Trustworthiness
  » Security, privacy, transparency, ethics, accountability, safety
» Use cases and applications
  » Repository of use cases and best practices for application domains

Standards activity is extensive in the AI field. As it is a transversal technology, affecting many other IT fields, it is being considered by many SDOs committees in addition to AI ones, such as robotics, vehicles, medical devices and financial services. A joint IEC and ISO technical committee (TC) on IT issues has been working on AI terminology for several years and has developed a suite of standards aimed at providing clear language and definitions on such areas as machine learning (ML), neural networks and natural language processing.

Standards can help increase the level of trust people have in AI. It is difficult to trust what cannot be defined, therefore, the lack of a common definition of a technology that is pervasive in peoples' lives and has the capacity to impact human rights and well-being can lead to distrust. By enabling a common definition to be reached, standards can ultimately help create trust in AI systems. Standards can also facilitate the understanding of AI systems which can also create trust in their outputs, decisions, recommendations and general ecosystem, thus enhancing the human–machine relationship. Furthermore, as humans are consumers of AI, in many cases unknowingly, standards can play a key role in providing protection to users, also ultimately leading to trust.

Despite the potential for standards to increase trust, standards-makers face challenges in the areas of governance, accountability, transparency and cybersecurity, and in how to standardize these aspects of AI. There is a need to foster a dialogue with various societal stakeholders not normally involved in standardization on AI and its trustworthiness. The IEEE Global Initiative on Ethics of Autonomous and Intelligent Systems brought together a diverse range of experts from technical as well as ethics backgrounds to discuss how to establish ethical and social implementations of AI that prioritize human well-being. This resulted in the Ethically Aligned Design documents and drove several standards development programmes under the IEEE 7000 series of standards addressing, amongst other issues, transparency and governance.[17]

UNIDO is also deeply engaged on this issue and is in the process of finalizing guidelines/principles for use of AI by small and medium enterprises in developing countries.

AI technologies such as ML and deep learning utilize big data. ML is the development of computer algorithms that learn autonomously based on data and information (see Case Study 1), while deep learning, which includes neural networks, uses reinforcement learning and has more autonomy to make decisions. One of the biggest concerns in AI systems is the capacity to cause perverse human-harming outcomes if bias is not properly managed and understood in the data sets and algorithms used. As this outcome results from the data and its respective weight, if there is a lack of understanding of the bias in the technologies and corrective action is not taken through modelling, misapplication of the AI systems could be perceived as human intention to manipulate outcomes, creating a distrust in the system. Acknowledging this, ITU-T has a Focus Group on ML for future networks including 5G, with one of its objectives being to identify aspects that enable safe and trusted use of ML frameworks. There is a crucial need for AI systems to be transparent (and to the extent possible, in the case of deep learning) about their intended purpose and decision-making processes and to be accountable to allow stakeholders to understand and challenge them. At the European level the EU established in 2018 the European AI Alliance, a multi-stakeholder forum engaged in a broad and open discussion of all aspects of AI development and its impact on society and the economy.

Case Study 1 – Promoting sustainable bush-processing value chains in Namibia[18]

Invasive bush species are a problem in Namibia. Converting it into animal feed and charcoal was deemed a viable solution to strengthen important sources of food and income. Based on a feasibility study, UNIDO proposed a strategy to deliver bush-based final products for agricultural, chemical and pharmaceutical purposes, as well as domestic use. NGGP, a special purpose production plant, is being operationalized for manufacture of high-value livestock feed, coal, chips, Arabic gum and other selected products utilizing invasive Acacia species.

Innovative digital technologies and know-how for sustainable bush thinning and harvesting were used specifically—the Machine Learning Model for Acacia species mapping based on remote sensing texture image analysis and satellite and drone supported image recognition for the agricultural sector. The ML algorithm was fine-tuned to provide yield predictions to enable the NGGP plant to produce high-quality bio charcoal and animal feed. This pilot plant is expected to have a multiplier effect and be reproduced in other locations in Namibia and the region. A branding and marketing strategy was designed to ensure the long-term resilience of the operation. Bush-based animal feed and charcoal acquired a brand name Bushtainable Harvesting - NutriPellets and Bushtainable Harvesting - BushBQ to emphasis the eco-branding philosophy.

The project contributes to SDG 15, i.e. removing invasive bush contributes to sustainable use of land and reduces land degradation, improves farming practices and productivity, as well as improves food supply for the local population (SDG 2). It also helps with water management and shortages (SDG 6) and the transfer of technological know-how and skills, developing job creation opportunities for local people in rural areas (SDG 8).

[17] https://ethicsinaction.ieee.org/

[18] Strategic Action Plan for Sustainable Bush Value Chains in Namibia, UNIDO, 2019

Standards can also create a solid basis to ensure inclusiveness through the management of bias that, if not well managed, has a greater possibility to cause harm. These challenges are common to all societies across the globe and will need to be dealt with at the international level. Standards are ideally placed to assist in this respect. A major joint standardization effort is the subcommittee ISO/IEC JTC 1/SC 42 on Artificial intelligence. It has established three sub groups: SG 1 covering computational approaches and characteristics of AI systems; SG 2 investigating approaches to establish trust in AI systems through transparency, verifiability, explainability and controllability; and SG 3 identifying use cases and applications in different AI application domains, e.g. social networks, and different use contexts, e.g. healthcare and smart home.

Considerations over gender equality play an important role in this respect. Further to considerations over the need to ensure data safety and responsible/ethical data processing, more practically, AI holds the potential to provide a multitude of benefits, such as the promise of better care and disease outcomes for women as a result of targeted analysis of women's healthcare data, avoiding data bias. AI also poses a risk of perpetuating (gender) stereotypes, fostering further discrimination on the grounds of sex and gender, and widening the digital gender divide. For example, using and benefitting from voice activated/voice recognition devices can pose a challenge for women (and other users, e.g. speakers of dialects), as AI is susceptible to data bias, identifying and better responding to default male users. Gendering of technologies is also problematic in this regard as digital assistants are oftentimes female by design and/or learning. Standardization activities for AI could be guided by inclusiveness and equity to avoid negative outcomes for gender equality.

AI has the capacity to exponentially change the way humanity lives, however, its accelerated pace is leaving behind vulnerable groups and communities. Standards can act as an enabler for AI to generate positive outcomes for people, planet and prosperity, thus contributing to achieve SDGs in a more efficient path.

While there are standardizations challenges in the technical aspects of AI such as coordinating efforts to ensure harmonized data models and semantics across different domains, the more fundamental challenge is how to develop standards that mitigate risks and negative impacts, including misuse, as AI evolve as socio-technical systems. In particular, we must elaborate upon how standards can assist in ensuring AI and big data are accountable, trustworthy, transparent and safe.

BLOCKCHAIN/DISTRIBUTED LEDGER TECHNOLOGY (DLT)

About the technology

Blockchain[19] and distributed ledger technology (DLT) is a rapidly evolving and expanding technology. The disruptive technology emerged in 2008, but the market has grown significantly since then. The global blockchain/DLT market value was estimated to be at USD 2.89 billion in 2019 and is projected to reach USD 137.29 billion by 2027, growing at a compound annual growth rate of 62.7% from 2020 to 2027.[20]

[19] N.B. Cryptocurrency is not covered by this publication.
[20] Allied Research Network - Blockchain Distributed Ledger Market

A *distributed ledger* is a type of database, shared, replicated, and synchronized among the decentralized network members with no central authority or third-party mediator like a bank. All records in the ledger are timestamped and given a unique cryptographic signature, thus providing a verifiable and auditable history that is highly resistant to unintended changes (i.e. tamper-resistant). Blockchain is a type of DLT that permanently records in a sequential chain of cryptographic hash-linked blocks. DLT and blockchain are useful wherever requirements for traceability, accountability, regulatory compliance, and authoritative data exist, such as finance, supply chain management, logistics and health (see Case Study 2). For example, in March 2020, the World Health Organization (WHO) unveiled its MiPasa-based blockchain programme to help convey information about the COVID-19 outbreak.

Case Study 2 – Feasibility assessment for blockchain in the Ghanaian cocoa value chain

UNIDO has developed a methodology to assess the readiness of a value chain to implement blockchain technology. With the support of the Global Quality and Standards Programme (GQSP), the methodology was applied in the Ghanaian cocoa value chain in 2020 and the Peruvian cocoa and coffee value chains in 2021. The assessment method allows governments and the private sector to make an informed and collective decision on adopting the right technology for their needs and to have a road map towards a blockchain solution adoption.

The methodology consists of three parts that are geared to answering the following questions:

1. SCOPING – Does this value chain need blockchain?

Identification of the issues or business problems in the value chain that could be addressed by implementing blockchain.

2. SCORING – Is this value chain ready for blockchain?

A more technical viewpoint on whether the value chain would be ready for implementing blockchain.

3. SOLUTION – What does it take to implement blockchain?

The assessment identifies benefits and makes final recommendations on requirements, next steps and stakeholders to be involved.

Central to the approach is a fact-finding mission to collect information on the potential benefits of and the possibilities for blockchain implementation in the value chain. On the ground information is gathered from questionnaires tailored to different value chain stakeholders.

The methodology only relates to an initial assessment of the readiness of a value chain for blockchain adoption not the actual implementation. The adoption of blockchain could contribute to SDGs by improving food safety and security (Goal 2), through improved transparency and traceability, and greater integration into global value chains for farmers, through increased competitiveness in international markets, potentially unlocking additional sources of income (Goal 8).

The DLT and blockchain landscape can be confusing because it is a unique combination of research in fields such as cryptography, consensus, game theory and distributed network technology, and is constantly changing. The majority of blockchain and DLT will operate in situations involving personal, private, company, government or otherwise sensitive data, therefore, security and privacy are challenges given the lack of best practices and standards. DLTs show much potential, but they require other technologies to be able to operate. This linkage and mutual dependency with other technologies necessitate a mutual reliance and interoperability between different DLTs and between DLTs and other technologies/systems.

BLOCKCHAIN/DLT OPPORTUNITIES	BLOCKCHAIN/DLT RISKS
» Traceable, transparent and secure and fully auditable information records e.g. financial systems and supply chain management; » Tamper-resistant and transparent systems facilitating record-keeping and promoting trust among participants; » Logistic and data efficiencies to convey information; » Empowers user control over information, e.g. identity management; » Can be deployed in smart contracts; » Decentralization and automation (assisted by smart contracts) of verification and approval processes to improve efficiency and productivity; and » Incentivizes (or discourages) certain human behaviours (e.g. saving energy, reducing CO_2 emissions) through programmable tokens.	» Potential infringements on human rights, freedoms and dignity; » Data privacy risks, e.g. in public blockchains; » Immutability of data if incorrect; » Uncertain legal framework, e.g. legal standing of smart contracts; » Cyber-security issues; » Criminal misuse, e.g. cryptocurrencies; » High cost of developing DLT; » High energy consumption, e.g. systems relying on proof-of-work; » Lack of accountability, e.g. permissionless systems; » Vulnerabilities in smart contracts if code is not properly audited; » Inappropriate handling of private keys, e.g. key custodianship; and » High demand of computing resources.

Role of standards for blockchain/DLT

The broad scope of application for blockchain and DLT and their range of impact means that there is a need for standards in the field, for example, in information security, privacy, compatibility and interoperability for any user or developer of the digital technology. Standard making is still relatively new for this digital technology and the standard landscape is uncluttered. A few SDOs have been predominately active in the field, including ANSI, DIN, IEEE, and ISO. IEEE was an early actor and has developed over 50 standards addressing the horizontal and vertical aspects of this frontier technology. ISO's Technical Committee (TC) 307 Blockchain and DLT is rapidly developing standards for the sector. The comprehensive review of standards at the international level identified standard making in blockchain/DLT broadly falls into the following four categories:

- Foundational
  - Terminology
  - Reference architecture
- Methods and approaches
  - Interoperability between different DLTs and between DLTs and other system components
  - Compatibility between technology and legal frameworks
  - Data format
  - Smart contracts
- Trustworthiness
  - Governance, security, privacy, and identity
- Use cases and applications
  - Repository of case studies

The benefits of standardization in the field are improved security, privacy, scalability and interoperability and enhanced governance. This could encourage the technology's widespread adoption, increase trust in the technology and stimulate greater innovation. However, the pool of experts with sufficient knowledge of DLT to participate in standardization is relatively limited, meaning inclusiveness in the standard-making process, whilst essential, is currently not being achieved. Women, people from developing countries and regions such as Africa and South America are underrepresented. Moreover, SDOs could consider taking into account structural limitations faced by low-income, developing countries in the standards they develop. SDOs can act as advocates of technology development that is responsive to different geographical, infrastructural and educational realities with the aim to eradicate barriers to participation and benefitting from new technologies. Use cases could include pertinent examples, such as that showcased by UN Women in which the IDbox "solar-powered device uses blockchain to create a unique digital identity and wallet in the absence of Internet or electricity using only a 2G mobile phone."[21] These types of low barriers to entry can be deployed in a variety of locations and settings, such as in humanitarian response. Furthermore, blockchain technology can have positive effects in promoting gender equality, for example, UN Women also reports that digital wallets have shown to provide displaced women with greater financial autonomy compared to physical money, which is oftentimes controlled by male family members.

Smart contracts are defined as a computer programme stored in a distributed ledger system wherein the outcome of any execution of the programme is recorded on the distributed ledger;[22] put simply, programmes stored on a blockchain that run when predetermined conditions are met. They are speedy and efficient because the contracts are digital and paperless, as well as being trustworthy and transparent as they involve no third party, are tamperproof and transactions are shared with participants. However, smart contracts have legal implications such as compatibility with existing legal frameworks, enforceability, language used, their legal standing, and use in automated and AI systems. ISO TC 307 on Blockchain and DLT is developing a suite of standards on smart contracts covering such topics as the technical aspects of smart contracts in blockchain and DLT systems, what smart contracts are and how they work, legally binding smart contracts and good practice in smart contract security. IEEE has also entered the standardization domain for smart contracts considering data formats for these legal contracts.

There are challenges for national lawmakers in developing legal frameworks applicable to DLT and blockchain, particularly in the financial services because the technology opens up cross-border activities and decentralized finance and the creation of new digital assets. Standards have a role in supporting national legal systems that seek to manage this new digital technology because international standards are transnational, being applicable in numerous jurisdictions. However, a balance is needed between a certain level of standards without hindering innovation. On the one hand, the lack of regulation limits the capacity of governments to cope with fraud, local regulatory compliance evasion, financing of illicit activities, scams and Ponzi schemes. On the other hand, it inhibits technology adoption and innovation, especially affecting entrepreneurs and start-ups which are often confronted with the uncertainty of incurring a legal problem.

Blockchain and DLT raises concerns, including criminal misuse, energy consumption, immutability as both a benefit and a risk, public safety, consumer protection, data protection and a lack of understanding by the general public. In addition, governance frameworks are needed for this digital technology as it impinges on privacy, identity, and data ownership and use (see Text Box 2). ISO TC 307 is developing guidelines for governance that set out a series of principles for good governance of blockchain and DLT systems. IEEE committees are looking into standards that are required for blockchain and DLT applications in energy, healthcare, agriculture, IoT and automotive sectors with a particular focus on building trustworthy end-to-end devices and systems.

Text Box 2 – Example international standard addressing privacy in DLT

Privacy and personally identifiable information (PII) protection issues are widely considered as a major barrier for the adoption of blockchain and DLT-based solutions. ISO/TR 23244:2020 Blockchain and distributed ledger technologies — Privacy and personally identifiable information protection considerations provides an overview of the issues and practical concerns related to privacy and PII protection identifying and assessing known privacy-related risks and the way to mitigate them, as well as the privacy-enhancing potential of blockchain and DLT.

Standardization efforts in blockchain and DLT are rapidly developing, helping to shape the digital technologies and encouraging innovation and user acceptance, however, the scale and diversity of the digital technologies means that standards-makers face the twin problems of the technology outpacing standards development and lack of adoption. Another risk related to standardization is the uneven progress reported across different industries. The "Distributed Ledger and Blockchain Technology Study Group" of the ANSI Accredited Standards Committee X9 notes that the needs of some economic sectors might not be adequately considered. Certainly, specialized standardization work would be needed according to the knowledge areas and legal requirements of different industries.

The many opportunities of blockchain are not without sustainability challenges. For example, blockchain has the capacity to change the way goods and services are transacted, however, its rapid growth fails to consider its carbon footprint. Standards can promote environmental balance and non-abuse of this technology for the planet and its inhabitants. Standards can also play a key role in

[21] https://blogs.worldbank.org/psd/can-blockchain-disrupt-gender-inequality
[22] ISO TC 307

defining proper energy consumption, particularly during the blockchain mining process, leading it to become a sustainable technology that ensures no harm to the planet. While the benefits will be seen by experience, the more blockchain advances, the more complex it will become for humans to fully understand its consequences. Standards can promote understanding of the effects of the technology, ultimately leading to sustainability for all.

INTERNET OF THINGS (IOT)

About the technology

The UNIDO Industrial Development Report 2020 defines the Internet of Things (IoT) as the next iteration of the Internet, where information and data are no longer predominantly generated and processed by humans (as most data created so far have been) but by interconnected smart objects, embedded in sensors and miniature computers that sense their environment, process data and engage in machine-to-machine (M2M) communication.

IoT relies on interconnections through the Internet's network of devices, machinery and objects, each uniquely addressable based on standard communication protocols. Today, there are more connected devices than people connected to the Internet. IoT is not a single technology but a complex ecosystem using various technologies applied in diverse settings. IoT applications span all major economic sectors including health, education, agriculture, transport, manufacturing and utilities.

IoT is becoming a common part of everyday life in G20 countries and beyond. The IoT global market value was USD 308.97 billion in 2020, a 23.1% increase on 2019 figures, and the Asia-Pacific region generated USD 120.85 billion because of the rapid adoption of IoT in developing countries, such as India.[23] Part of the underlying infrastructure of the IoT is M2M communication, i.e. SIM cards embedded in machines,[24] such as automobiles or sensors, which allow communication between devices.[25] In 2017, the United States had over 10 times the quantity of M2M SIM cards per 100 people compared to India, while China had 44% of M2M subscriptions, the largest share worldwide.[26]

In terms of achieving inclusive and sustainable industrial development, IoT offers numerous possibilities. For instance, UNIDO's Sustainable Technology Promotion Platform (STePP) has harnessed IoT to increase geothermal energy production capacities in Kenya, thus reducing dependence on fossil fuels.

Role of standards for IoT

Standardization activity is high in the IoT field. It is a significant prerequisite to achieving interoperability between products and between different solutions, applications and domains. Giving rise to interconnected devices is the intention of IoT. The standards scene is complicated. There is a bewildering list of standards and standard-making organizations engaged in standards in the IoT landscape. The comprehensive review of standards at the international level identified standard making in IoT broadly falls into three categories:

- » Foundational
  - » Vocabulary
  - » Architecture
- » Method & approaches
  - » Interoperability
  - » Characteristics of IoT systems
  - » Sensors, applications and domains
- » Trustworthiness
  - » Trust, identity, privacy, protection, safety, and security

Standardization of vocabulary, terms and definitions in the realm of IoT can reduce the level of ambiguity and promote understanding. International standards have an important role to play in establishing a single, homogenous body of terminology in a field, as shown in Text Box 3.

[23] Fortune Business Insights - Market Insights IoT 2021
[24] Excluding consumer electronics
[25] OECD Toolkit for Measuring the Digital Economy, 2018
[26] Groupe Spéciale Mobile Association (GSMA) tracks the number of M2M subscriptions worldwide.

Text Box 3 – Internet of Things vocabulary standard[27]

The international standard IEC 60050-741 provides a definition of Internet of Things, along with related terms and definitions, as an infrastructure of interconnected entities, people, systems and information resources together with services which processes and reacts to information from the physical world and virtual world. This definition is to be used by all IEC Technical Committees.

Standardization for architectures for common service frameworks can help eliminate IoT silos. Interoperability in IoT has to be considered at different layers from component, to communication, information, function and business layers, i.e. architectural frameworks. Many IoT applications are deployed in silos, e.g. one application using one communication network to interact with devices or sensors. IoT silos impede operational scaling or resource reuse. Standards can play a key role in encouraging a common language among machines' systems, ultimately leading to interoperability as a common language among machines leads to proper optimizations. As the IoT market matures, IoT applications will employ distributed architectures. All require new and standardized enablers. One attempt to address the lack of interoperability in industrial IoT (IIoT) is the collaboration between Industrial Internet Consortium (IIC) and oneM2M (see Text Box 4). IoT in different sectors are being rapidly developed by big tech companies, therefore, standards can act as a fair trader to avoid monopolies and provide opportunities for all. IoT is advancing through niches, creating silos, closed ecosystems and avoiding proper integration. Standards can promote interoperability, leading to cost reduction and ultimately providing opportunities for emerging developers.

[27] https://webstore.iec.ch/publication/66698

Text Box 4 – Collaboration on IoT architecture for interoperability[28]

IIC is a membership organization that seeks to accelerate the adoption of IIoT by enabling trustworthy industrial Internet systems and has a testbed programme for industrial innovation for new technologies, applications, products, processes and services. oneM2M brings together several major regional ICT SDOs, such as ARIB (Japan), ATIS (North America) and TSDSI (India) to collaborate and develop and manage technical standards to enable IoT solutions. IIC and oneM2M have different origins and approaches in addressing IoT and IIoT architectural challenges, but they share common objectives in helping industries achieve interoperability and reusability and are committed to develop common standards for a common service layer applicable to different industrial segments.

In 2017, IIC and oneM2M announced their agreement to work together to contribute to the creation and development of the Industrial Internet. Under this agreement, the organizations will promote the digital economy by preventing fragmentation and by harmonizing various aspects in the IIoT. Joint activities between the IIC and the oneM2M will include:

» Collaboration, review and two-way feedback pertaining to IoT use cases, requirements and reference architectures;

» Feedback to oneM2M standards from IIC testbeds and interoperability events;

» Feedback from oneM2M to IIC Industrial Internet Reference Architecture; and

» Joint workshops, showcases and interoperability events.

[28] https://www.iiconsortium.org/press-room/09-27-17.htm

A crucial factor driving the IoT market growth is the increasing adoption of smart sensors. Smart sensors measure the external environment and physical inputs, e.g. temperature, light and pressure, and convert them into raw data stored digitally for analyzing the processes. With the rapid technological development of sensors, wireless sensor networks (WSNs) will become the key technology for IoT. IEC notes[29] that IoT standard making for WSNs is characterized by disunity with a lack of coordination between SDOs, incompatible as different SDOs develop different unique standards and divergent since standards are developed behind the curve of application development. A major prerequisite in achieving the interoperability of smart sensors such as WSNs, not only between products of different vendors, but also between different solutions, applications and domains, is standardization. For example, IEEE 802.5.14 is the most relevant communication standard for the WSN and ISO/IEC JTC 1 subcommittee (SC 31) is one of the major standardization drivers with its ISO/IEC 18000 series of standards. The development of overarching international standards would allow for greater cross-border trade and production, as well as an improved common technical understanding.

Standards are leveraging IoT technologies to create more efficient, responsive, make-to-order systems. An important feature of IoT is data management. Vast amounts of data and information are collected by all Internet-connected devices raising cybersecurity and privacy issues as the technology is vulnerable to attacks. Standards can optimize the response to threats and play a key role to provide protection to data, ultimately leading to a safer and more secure ecosystem. Cyber-risks have more than quadrupled since 2002.[30] SDOs such as the National Institute of Standards and Technology (NIST) cybersecurity programme for IoT supports the development and application of standards, guidelines and related tools to improve the cybersecurity of connected devices. Furthermore, the more interconnected devices become, the more in demand and overextended IoT cybersecurity experts will also become. By promoting an understanding of the field, standards can aid in attracting more experts and facilitate its expansion.

As IoT systems get more integrated and complex, issues related to trustworthiness, i.e. privacy, identity, trust, security, protection and safety (TIPPSS), become more important to users. Standards can address privacy issues on personal data and accountability in data usage and lack of transparency that could negatively impact personal freedoms and infringe upon human rights. IEEE is focusing on critical aspects of TIPPSS in IoT, for example, the project IEEE P2933 on standards for Clinical Internet of Things (IoT) Data and Device Interoperability with TIPPSS.

IoT has numerous applications. IoT makes factories more intelligent, safer and more environmentally sustainable. IoT connects industry to a new range of smart manufacturing solutions to run the production, streamline product development and manufacturing processes (see Case Study 3). Homes have smart appliances to become smart homes and integrated, smart, sustainable cities are being invested in, particularly in the EU, and smart infrastructure becomes achievable with IoT. For example, smart city and digital technology standards developed by ITU-T Study Group 20 Internet of Things and Smart Cities and Communities help cities ensure their investments in digital technologies deliver maximum positive results for their citizens and businesses and also assist cities in harnessing these new technologies to implement SDGs. Another example application of IoT is the UNIDO project, in partnership with the Government of Japan, to improve the efficiency of geothermal electricity production in the Great Rift Valley Region in East Africa. The project aims to install sensors in power generators and turbines to detect temperature and vibrations, and the data extracted from the process then will be computer-analyzed to increase the efficiency of the geothermal power plants in the region. The technology allows companies to remotely monitor and manage the production and distribution of energy in real time. The technology will also improve the plants' operational safety, as geothermal power plants are usually built in earthquake-prone areas. The possibility of managing the plants remotely also has clear advantages for avoiding employees' exposure to chemicals often released by geothermal power plants.

In spite of the promises of IoT systems, earlier in 2021, the European Parliament's Policy Department for Citizens' Rights and Constitutional Affairs published a briefing outlining the dangers of IoT-related abuses, which stipulates that women face an increased risk of being affected by gender-based violence and "tech abuse" enabled or facilitated by IoT. Ethical considerations are already being addressed by standards, especially over data protection, but there is room for SDOs to mainstream further approaches aimed at counteracting and preventing possibilities for misuse and, arguably more importantly, abuse. Provisions pertaining to the usability and also the sale of IoT products need to be gender-responsive. For example, the marketing of digital or digitally enhanced products is oftentimes geared towards men, and it has been noted that it is mostly men who make related purchasing decisions and control the installation/setup and maintenance of the new technology.[31] As pointed out in a European Parliament briefing, IoT devices often require one designated administrator as well as password protection; this type of control increases dependency and the vulnerability of women and girls in the home. Smart door locks, for instance, are at risk of being abused by controlling, and effectively granting or denying, entry and exit to the home.

Digital twins help transform the physical assets of industries into a virtual representation and aids in controlling, examining and viewing the operations based on the digital platform. For example, ISO/IEC JTC 1/SC 41 Internet of things and digital twin has published 32 standards in the IoT landscape on IoT architecture, interoperability and applications, and has working groups specifically dedicated to digital twins and their applications.

[29] IEC White Paper IoT – Wireless Sensor Network 2019
[30] The Economist June 19th 2021
[31] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/690358/IPOL_BRI(2021)690358_EN.pdf

Case Study 3 – Smart manufacturing in the automotive industry – Colombia

From 2019 to 2020, Solocauchos S.A.S., a Tier 2 automotive sector supplier in Colombia, participated in the World Class Competitor project supplier upgrading activity. This provided tools and methodologies to increase productivity and quality of participating companies and contributed to SDG 9—delivering innovation in industry and promoting prosperity. Over 2 years, the company received coaching and training on Lean Manufacturing tools, Six Sigma, Theory of Constraints and quality management approaches.

Solocauchos developed its own real-time flow and production control software called SWRF-DRO3 (basic unit). The unit receives real-time data from the production line to determine the process status and monitor the production cycle. The software was developed to provide real-time information in order to increase productivity, profitability and innovation by the integration of knowledge on Overall Equipment Effectiveness (OEE), IoT, and E-finance, i.e. link between production systems measurement technology and enterprise financial information.

Solocauchos' participation in UNIDO activities resulted in the enterprise increasing its productivity and making estimated production costs savings in the first year of USD 35,300. Further analysis in 2020 revealed an additional USD 10,000 savings in new processes improvements. The company's software facilitates automation, digitalization and better control of process and resources, and has been successfully sold to and adopted by 2 other automotive enterprises.

IoT developments are outpacing standardization and the lack of adoption of standards by IoT applications are issues for the sector. Numerous standards have been developed for IoT by a range of international SDOs and international bodies. The lack of harmonization is an impediment to IoT growth affecting the reusability and interconnectedness of things in the IoT ecosystem, and increased coordination is needed between SDOs to rectify this problem. Increased coordination is required between standard-making organizations to achieve harmonization and reduce divergence amongst standards, and increase the pace of standardization for the IOT domain.

ROBOTICS

About the technology

Eurostat has defined the robot as "a machine, programmed by a computer, capable of carrying out a series of more or less complex actions automatically." Robots can be industrial robots or service robots. An industrial robot is an automatically controlled, reprogrammable and multipurpose manipulator in three or more axes, either fixed in place or mobile, used in industrial applications such as manufacturing processes (welding, painting and cutting) or handling processes (depositing, assembling, sorting and packing). A service robot is a machine that has a degree of autonomy and operates complex and dynamic interactions and coordination with persons, objects and other devices (when used, for example, for cleaning, surveillance or transportation).

The field of robotics is complex, diverse and rapidly evolving; for example, a recent development is soft robotics which takes inspirations from living organisms to make flexible robots with highly compliant materials. Robots operate in many different settings and have distinct functions such as industrial robots; service robots, including medical ones; robots in logistics; field robots, e.g. agriculture; and personal and domestic robots, e.g. care robots and vacuum cleaners.

In 2019, 2.7 million industrial robots operated in factories worldwide—an increase of 12% from 2018—equivalent to a worldwide robot density in manufacturing of 113 robots/10,000 employees.[32] Sixty-seven per cent of industrial robots operate in three sectors: automotive, electrical and electronics and metal industry. The sales value of the professional service robot sector increased by 32% to USD 11.2 billion worldwide (2018–2019) and medical robotics accounted for 47% of this sector's turnover in 2019. The COVID-19 pandemic created high demand for robotic solutions for tasks such as disinfection, logistics in factories and warehouses and home delivery.

Collaborative robotics is when automatically operated robot systems share the same workspace with humans and refers to a system or application rather than a particular type or brand of robot. The adoption of human–robot collaboration is on the rise and installations grew by 11% in 2019, however, the market is still in its infancy at only 4.8% of the total industrial robot market.[33] Asia remains the strongest market for industrial robots with China being the region's largest adopter, and India has doubled the number of industrial robots operating in the country's factories in five years to 26,300 units.[34]

Role of standards for robotics

International standardization in robotics became more concentrated as robots began to increasingly possess a degree of autonomy. ISO set up its first committee in 1983 on "robots for manufacturing environment" and

[32] World Robotics Report 2020
[33] International Federation of Robotics World Robotics Report 2020
[34]https://ifr.org/ifr-press-releases/news/record-2.7-million-robots-work-in-factories-around-the-globe

upgraded the committee in 2016 to cover the broader field of robotics.[35] The ISO committee TC 299 on Robotics has published 26 standards with a further 11 under development.[36] The comprehensive review of standards at the international level identified standard making in robotics occurs in the following categories:

- Foundational
  - Vocabulary
- Method and approaches
  - Performance and testing
  - Health and safety
  - Security
  - Management
- Trustworthiness
- Ethics

The expansion of traditional caged robots capable of handling all payloads quickly and precisely to new collaborative robots that work safely alongside humans, fully integrated into workbenches, raises issues of protecting people from injury and their employment being economically devalued. Standardization around the parameters under which humans and robots can work together is increasingly important as more collaborative robotics are developed. Standards can also facilitate the common understanding of AI systems among all affected actors, leading to trust of the technology and extending to their outputs, decisions and recommendations and general ecosystem, thereby enhancing the human–machine relationship. While the focus is mainly on robots understanding humans, there is room for humans to understand robots as robots can be better utilized when they are designed to work in partnership with humans, and partnership works when there is mutual understanding. Standards can play a critical role in facilitating human–machine understanding, thus contributing to trust, increased efficiency and productivity in organizations. Closer interaction between human systems and robotic systems will drive the demand for standards on safety management, privacy, identity and independence as more complex and intuitive AI is integrated into robotics. For example, the international standard ISO/TS 15066 gives specific, data-driven safety guidance needed to evaluate and control risks when robots work alongside humans in collaborative working spaces.

As the field of robotics evolves, standardization efforts will need to be broadened to support the sector's development. Standards can ensure stakeholder concerns about service robots, e.g. care robots, or robots in medical settings, are taken into account. For example, IEC has published standards on the basic safety and performance of medical robots, however, medical robots are diverse in their form and function, such as robotic exoskeletons that provide external support and muscle training for rehabilitation, and appropriate standards are needed. Autonomous Internet-connected robots of all types will challenge current rules on data protection and privacy, particularly where users are unaware of how much and for what purpose data are being collected. Ensuring the safety of data always remains a major concern when using robotic solutions. There is currently no clarity on the ownership of the data the robot has, and disputes arise from whether the owner of the data is the end-user, the robot manufacturer, or its software provider. Standards can facilitate a path to implement proper data management, ultimately leading to trust. The IEEE Standards Association global initiative on the ethics of autonomous and intelligent systems considers some of these data protection issues. Another issue related to data is that data collectors often do not foresee the uses of the data before or while collecting it, only realizing its potential uses once is has already been collected at scale. It is important for standards to be developed regarding clear intimation of the data's purposes, and for those stated purposes to not later be expanded upon without the data provider's knowledge or consent.

[35] https://committee.iso.org/home/tc299
[36] https://www.iso.org/committee/5915511.html

Standards can also ensure ethical and cultural aspects are considered to make robots acceptable to society, particularly when automation eliminates jobs. The OECD Policy Brief on the Future of Work – Going Digital: The Future of Work for Women notes that some large industries with high shares of women are at a high average risk of automation, though summing across all industries, the average risk of automation is similar for men and women.[37] It is important for SDOs to be aware of any gender-specific constraints (e.g. in historically women-dominated occupations that can be more easily automated) and ensure concerns of adequate representation of women generally, and vulnerable workers specifically, are reflected in standards to minimize detrimental effects of the technology on certain members of society, thus encouraging inclusiveness.

Although standardization is only just beginning to address trustworthiness, IEEE has a project developing an ontological standard for ethically driven robotics and automation systems. Standards and guides are being developed on subjects such as:

- Safety issues in the increasingly diverse range of human/robotic interface situations;
- Integration of robot's autonomous features to other digital technologies particularly AI and associated risk management, and cyber security and privacy issues;
- Application of robots in diverse settings such as medical and care services;
- Environmental impact of robots, such as material selection to allow recycling, energy use in operation and disposal; and
- Trustworthiness issues linked to the cultural, ethical and social aspects of deploying robots and human rights issues as robots pervade peoples' lives.

The benefits of standards in the sector are to increase safety and protect humans, to specify technological aspects such as performance and recyclability and to contribute to cost reduction and innovation as well as to engage with diverse stakeholders to take account of their views as robots extend into different domains in society. However, advancement in robotics with AI and ML mean standardization is being outpaced by the technological developments' resulting inefficiencies from a lack of compatibility and divergence with basic parameters such as safety.

As the main technology for operability of robotics is AI, standards can play a key role in the development of reliable AI that will define proper management on bias reduction in AI systems, ultimately leading to inclusiveness. Development of robots has the capacity to offer a better life for those that are in need, the challenge lies in leaving no one behind. Standards can act as an enabler for robotics to benefit people, planet and prosperity, thereby also contributing to inclusiveness.

[37] https://www.oecd.org/employment/Going-Digital-the-Future-of-Work-for-Women.pdf

3D PRINTING

About the technology

Eurostat defines 3D printing/additive manufacturing as "…the use of special printers to create three dimensional physical objects from 3D model data by adding layer upon layer through material extrusion, directed energy deposition, material jetting, binder jetting, sheet lamination, vat polymerization and powder bed fusion. Additive manufacturing is contrasted with subtractive manufacturing methods, which use moulds or rotating milling cutters to remove material from a solid block of material."

3D printing is a popular term that refers to a broad range of additive manufacturing (AM)[38] techniques. AM is the process whereby a material is usually layered to create solid objects from computer-aided design (CAD) models or 3D scans under computer control. The AM sector is relatively young, and will develop and mature over time as knowledge of the technology grows. Additive manufacturing technology (AMT) is primarily used in the industrial and business sector, followed by electronic goods, motor vehicles and medical devices. Wohlers Report 2021 found the AM industry expanded by 7.5% to nearly USD 12.8 billion in 2020. Due to the pandemic, growth was down considerably compared to the average growth of 27.4% per annum over the previous ten years.[39]

AM has a smaller environmental footprint than traditional manufacturing and contributes to circular economy aims, reducing material usage and waste. Instead of milling a workpiece from a solid block of material, an AM machine can read CAD files to determine the time and material needed to build up 3D structures from fine powders or liquids, reducing wastage and saving time. AM allows for more fluid product development and design because it permits the manufacture of prototypes and parts on-demand, allowing the freedom to redesign and innovate without significant penalties of time and material costs.

AM is an enabling technology. It produces parts that may not have been feasible with existing technology, creating endless possibilities for innovation. For example, regular and customized hearing aid shells, dental implants and prosthetic limbs have all been successfully produced by AMT. AM also enables decentralized manufacturing of consumer goods eliminating unnecessary transportation and multiply assembly processes. This could potentially impact the locations of manufacturing facilities, rebuilding lost manufacturing bases—such as those lost in Europe—or decentralizing and localizing manufacturing close to population centers, reducing transportation costs and climate change impacts.

3D printing may be especially useful in providing cheap and durable construction materials for the housing sector, as well as reducing industrial waste, thus addressing Goal 9 of the 2030 Agenda to "build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation." It also has great potential to meet needs in the medical manufacturing sector amidst the COVID-19 pandemic, especially for production of personal protective equipment.

[38] 3D printing and AM are used interchangeably.
[39] Wohlers Report 2021

Role of standards for 3D printing

One of the stumbling blocks to the technology's wider application is the lack of supporting standards. International standardization has been slow to develop for AMT because interest in standards has been limited, which has led to a proliferation in national standards. American Society for Testing and Materials (ASTM) International created a committee (F42) to create standards for AMT in 2009 and ISO entered the field in 2011 establishing TC 261 on AM. The EU project for Support Action for Standardisation in Additive Manufacturing (SASAM) delivered a roadmap for standardization activities for AM in 2013 that included standards for process stability, product quality, materials used and productivity.[40] As in most standardization activities, women are largely underrepresented in AM-standardization activities as well as in the industry in general (similarly as in robotics and other tech sectors). While professional women's associations have been established over the last few years, the gender gap in 3D printing can in part be attributed to a lack of girls and women in STEM fields, with a lack of female role models, and limited industry awareness of underrepresentation being problematic. It is important for SDOs to consider underrepresentation of women in the industry when developing standards for AM and to ensure standards developed account for women, thus encouraging inclusiveness.

The plethora of standards means there is a need for international standards for quality, materials, testing, safety and performance to guarantee a level of reproducibility in AMT and to contribute to innovation in the field. To avoid work duplication, or worse, the development of conflicting/competing standards resulting in market confusion, ISO and ASTM established a working framework as part of the Partner Standards Development Organization (PSDO) cooperation agreement to develop standards for AM in a variety of industry-specific applications, settings and conditions. The collaboration in ISO TC 261 agreed a common structure in AM standards and has resulted in 19 international standards being published with a further 37 under development including standards for AM for aerospace and construction and environmental, and health and safety requirements for specific AM machines. The comprehensive review of standards at the international level identified standard making in the 3D printing field occurs in the following categories:

- Foundational
  - General concepts
  - Fundamentals and vocabularies
- Method and approaches
  - Common requirements or generally applicable (e.g data format, design guidelines, hardware and software, applications) to most types of AM materials, processes, and applications
  - Testing
  - Quality and safety
- Category standards
  - Specific to a feedstock material e.g. metal powders, process/equipment (e.g. powder bed fusion) or finished part (e.g. mechanical test methods)
- Specialized standards
  - Specific to a material (e.g. titanium alloy powder), process (e.g. powder bed fusion with nylon), or application

Notably, unlike other digital technologies such as AI, big data, blockchain and IoT, standards in AM are not being developed in the trustworthiness category. This is because AM technology does not as yet have the potential to infringe on human rights, freedoms or dignity. However, the increase in available design files that can be easily and often freely downloaded and 3D printed poses a risk to intellectual property (IP). In addition, there is a lack

[40] European Commission Digital Transformation Monitor: The disruptive nature of 3D printing, 2017

of clarity in many legal areas in AM, including patents, copyrights and trademarks and printing of items used illegally.

AM biomedical systems are capable of printing cells, proteins and organs and research is underway in bio-printing of skins, organs, bone and cartilage. Standards-makers have entered the AM biomedical field, for example, IEEE has projects on standards for In Vivo Evaluation of 3D Printed Polymeric Scaffolds in Bone Defects and Artificial Joint Implant Design Modelling for Medical 3D Printing. This new field for AMT raises many issues such as safety and reliability, acceptance and ethical issues for medicine.

Further safety concerns relate to certain types of materials used in AM that can release particulates and other harmful chemicals into the air, while others are flammable or combustible. Standards will help to shape the industry and ensure that AM processes, materials and technologies are safe and reliable as well as ensure compatibility of AMTs, impacting the well-being of people and the planet. AM can shorten development cycles of weapons, decrease production costs, and simplify witting and unwitting transfer of military hardware and know-how. This applies to every conceivable weapon category, from small arms to weapons of mass destruction. Standards will play a critical role to frame the scope of these developments for the proper use of AM technology and to avoid harming people and the planet, ultimately increasing safety. An AM security concern relates to the fact that 3D printers include computers and run software that could be vulnerable to security issues that bad actors could exploit. To mitigate this issue, standards can play an important role for 3D printing vendors to make secure coding and design a core part of their development process.

From a sustainable development standpoint, 3D printing can also be deployed for the construction of affordable housing in developing countries as well as for the easy provision of personal protective equipment to combat COVID-19. The adoption of AM is leading to shorter and more localized and collaborative value chains. Standards have the potential to offer sustainable benefits by improving resource efficiency in production and use phases as manufacturing processes and products can be redesigned for AM. Further contributing to sustainability, the capacity of AM to create extended product life can benefit from standardization through sustainable socio-economic patterns such as stronger person–product affinities and closer relationships between producers and consumers. AM also has the capacity to be processed in a way that is energy saving and optimizes the use of materials. In this regard, standards can play a key role in defining proper by-products during the printing process, leading AM to become a sustainable technology that ensures no harm to the environment and the planet.

Standards can also help guarantee a level of reproducibility, and give business and manufacturers the much-needed quality assurance in AM processes, materials and technologies. The quality and durability of surface finish and mechanical properties are of concern, particularly for the usage in final or functional parts manufacturing, and standardization has an important role to play in providing users with the necessary standards for a variety of industry-specific application. For example, F3122 Guide for Evaluating Mechanical Properties of Metal Materials Made via AM Processes.

AM industry is growing rapidly, helped in part by a big fall in the price of AMT increasing the accessibility of the digital technology to enterprises, and the innovation in uses for the technology. Standardization efforts have been dispersed and uncoordinated and late to the market, however, standards-makers have an opportunity to help AM producers and consumers by providing a common set of standards that benefits the market by specifying requirements for such areas as quality, performance, test and inspection methods, environment, health and safety, and design and data format. Better coordination between SDOs will prevent duplication of efforts and the development of standards to provide the technical rigor for AM and delivery consistency, and therefore, confidence in the technology for the market.

UNMANNED AIRCRAFT SYSTEMS

About the technology

Unmanned aircraft systems (UAS)[41] are guided remotely or autonomously and vary greatly in size, capabilities and cost. UAS are composed of an unmanned autonomous vehicle (UAV), commonly referred to as a *drone*, a ground-based controller of the UAV and the system that connects the two. The global commercial drone market size was valued at USD 13.4 billion in 2020, with an estimated 7 million flying in American skies in 2020. The most extensive use is in China and Japan.[42]

The application of UAS has expanded into a wide range of uses, such as detecting forest fires, monitoring traffic, disinfecting areas, delivering parcels and surveying agricultural land. They can be integrated with AI and ML to understand their surroundings better and give analytical feedback and real-time, data-driven decision-making ability to their users. AI-powered vehicles also enable users to collaborate and access information from other drones; coupling this with predictive learning software means faster data analysis, which enables a variety of actions to be taken. The advent of 5G and the integration of cloud computing technology with drone technology is expected to increase growth in the commercial drone market with the global drone market size forecasted to grow to USD 42.8 billion by 2025, according to Drone Market Report 2020–2025.

Role of standards for UAS

The use of UAS is more frequently and widely distributed, causing growing concerns about their uncontrolled use in urban areas and near airports. This poses safety issues therefore, these new airspace users—civil, commercial and leisure—need to be integrated into the airspace not only to ensure the safe operation and prevention of harm to people, but also to realize this growing industry's potential. There is a need to develop a traffic management system for UAS and define how it will work technically and

[41] In this publication, the terms UAS and drones are used interchangeably.
[42] Global Drone Market Report 2020-2025

institutionally, however, regulations are inconsistent or lacking. Standards can facilitate the structure of such traffic management system, thereby contributing to safety and security. Some countries, such as France and the United Kingdom, have clearly defined laws that stipulate such things as line-of-sight operation, non-urban use, drone weight limits and often a flight altitude ceiling. Other countries, in the absence of regulations, have banned drone use. Standardization could play an important role where there is a lack of regulation and also in support of existing regulations developed by national Civil Aviation Authorities (CAA).

The comprehensive review of standards at the international level identified standard making for UAS occurs in the following categories:

- Foundational
  - Terminology
- Method and approaches
  - Health and safety
  - Air space sharing and coordination
  - Quality
  - Testing
  - Training
  - Remote identification

The low level of existing standardization and the complexities of sophisticated, varied and incompatible UAS present a significant challenge in standards development. Most of the standardization activity has concentrated on the technical aspects of UAS with some attention to specific operational situations and the training of drone operators. ISO TC 20 SC 16 on Unmanned aircraft systems has published 5 standards with a further 25 under development on topics such as UAS classification, design, manufacture, operation, including traffic management and training of drone users, maintenance and safety management (see Text Box 5). IEEE standardization efforts have focused on drone application framework in standards that specify Interface Requirements and Performance Characteristics of Payload Devices in Drones (IEEE P1936.1 and IEEE P1937.1).

Text Box 5 – Safe operation of unmanned aircraft systems standard

The ISO21384-3, *Unmanned aircraft systems – Part 3: Operational procedures* - standard specifies internationally agreed and accepted requirements for safe commercial UAS operations and applies to all commercial UAS regardless of size, categorization, application or location and represents the international best practice.

The ever-increasing range of applications for UAS means that standards are required to bring about a globally harmonized airspace for routine UAS access that will increase the commercial market while maintaining safety and increasing airspace efficiency. There is a lack of standardization activity concerning the use of UAS and their impacts on privacy issues and potential infringements of people's rights through the misuse of drones to monitor and collect data. Standardization can mitigate this risk, resulting in a more secure environment. Moreover, despite the increase in production at different scales, still today there are no international supply chain regulations. Security and privacy remain issues as a result of certain countries monopolizing the production of UAS. Standards can help to ensure fair and trustful systems used in UAS. The increase in autonomous vehicle production and its accessibility raises the risk of potential targeted attacks if leaks in their security are not well managed. This technology integrated with AI can better understand their surroundings, map areas accurately, track and monitor the movement of specific objects, including people, as well as offer precise analytical feedback. Therefore, there is a need to develop standards in trustworthiness for UAS, particularly to protect human rights and privacy.

While the market for consumer drones is expanding, it has been observed that women are once more starkly underrepresented and underserved when it comes to skills building and other training as well as engaging with the community of drone professionals. UAS are largely marketed towards men, and aspiring girl and women drone pilots would benefit from more female role models. It is vital for SDOs and educators to ensure that girls and women are represented and encouraged as well as adequately capacitated to pursue careers in this field.

PART 4: **PRINCIPLES**

PRINCIPLES FOR STANDARDS IN DIGITAL TRANSFORMATION

The rapid and extensive adoption of digital technologies and their far-reaching pervasive impact on people, their prosperity and the planet suggest a core set of distinct principles is needed to guide standards developed for digital transformation governance. Standards that account for these principles contribute to the integral process of risk management, helping to avoid undesired outcomes associated with digital technologies while ensuring the technologies achieve their functional goals, benefitting people and the planet.

The comprehensive review undertaken of the current developed digital-related standards and SDO committee activities in the digital space, particularly for the seven big digital technologies of the 4IR, identified the following seven principles for standards to be placed in the center of standard making:

» Trustworthiness,
» Inclusiveness,
» Sustainability,
» Interoperability,
» Safety and security,
» Data privacy, and
» International collaboration.

The principles relate to the impacts of new technologies in the digital era and are based on the nature and internal mechanism of standardization. They cover notable concerns about the complex impacts of new technologies on people and the planet, in terms of well-being and ethics, as well as the key factors emerging from the evolving discussions about what should be considered in standard making in the context of digital transformation.

It can be observed that many standards related to new technologies address issues of productivity, *interoperability*, and *safety and security*. While issues like *sustainability, inclusiveness,* and *trustworthiness* are also sometimes addressed, the cases are the exception rather than the rule. There is potential to upscale these efforts in view of achieving sustainable development. Standardization can play a key role in digital transformation governance and should, therefore, include considerations in line with the suggested principles.

Data privacy is an emerging topic of global interest where standards can play a key role.

All these efforts cannot be made in isolation. *International collaboration* is key to strengthening the role of standards in digital transformation governance and has a truly global impact on sustainable development.

TRUSTWORTHINESS

Trustworthiness encompasses the full range of topics at the cutting edge between 4IR technology and humans, their rights and society. It encompasses human rights and the characteristics of accountability, transparency, robustness, equity, privacy, and ethical and lawful use of technology. A key component of trustworthiness is how ethical concerns raised by digital technologies are handled.

Trustworthiness addresses digital technology and its impacts in the widest societal context rather than a narrow technical one. It is particularly relevant to AI and big data (see Text Box 6), blockchain/DLT and IoT. It captures the interface between humans and new technology in its broadest way. Not all digital technologies have the same impact on humans. For example, drones for remote physical surveillance and monitoring utilizing facial recognition CCTV cameras raise civil rights issues. The scope of impact depends on the technology type and its application, therefore, the application of the trustworthiness principle will vary.

As a result of their impacts on humans, trustworthiness issues are increasingly being considered in standardization. Trustworthiness-oriented standards set out guidance on best practices for managing, controlling and using technology to provide a trustworthiness framework. However, the voluntary nature of standards means that regulators have an essential role in setting the legal framework and appropriate laws to protect fundamental human rights and make the technology human-centered.

Achieving trustworthy digital technologies requires technology-related ethical issues to be addressed. Ethics is set in a cultural context and framed by society and the laws that govern that society. Concerns vary depending on the stakeholder group, the risks and impacts of the technology and who has responsibility for the technology in operation. For example, if technology fails, questions arise regarding who or what monitors, adapts or interrupts its process, and whether it is another system or a human being. Standards can help describe the ethical features associated with a piece of technology and the risk assessment needed. Moreover, they can act as a guarantor of equity related to gender and marginalized groups in 4IR technology design and application, avoiding unintended biases.

Text Box 6 – AI and big data bias and protection

AI and big data are interconnected and have significant societal impacts and risks as AI allows for collecting vast quantities of data, and citizens unknowingly, unwittingly or mandatorily have their data collected. This harvested data is available for many uses, including tracking payment habits, a person's location, personal circumstances, relationships and health. AI systems can have failings that introduce data bias or poisoning and model extraction and evasion, therefore, the systems require more complex privacy-preserving techniques. The development of standards that deal with the entire life cycle of AI systems—from the inception of the idea, during development, monitoring and disposal—can help achieve accountability and transparency and build trust in the technology. Such standards can support legislation like the EU's General Data Protection Regulation (GDPR) that provides measures to remedy the misuse of personal data.

INCLUSIVENESS

The inclusiveness principle seeks to address two interlinked problems in the digital transformation, namely unequal representation in the standards development process and groups of people being excluded and/or negatively impacted by new technologies.

Technological experts and users (e.g. businesses and governments) are the majority participants in standards development. The inclusion of a broader range of societal stakeholders (e.g. consumer groups, labour, NGOs, civil society and faith groups) can highlight the socio-ethical impacts of digital technology, which are increasingly essential considerations in standard making to mitigate the societal exclusion impacts of the digital transformation. Standardization has a role in helping manage and mitigate these impacts to ensure inclusivity and equity and to challenge bias by applying the inclusiveness principle.

No particular person, organization or interest group should dominate standards-making activities. However, participation in standardization is not geographically even, or gender or culturally-balanced, often excluding minorities and indigenous people. There is a predominance of experts from developed countries, with LDCs most underrepresented and unable to participate, for example, because of a lack of financial and technical resources, technical experts and English language skills. Women are also significantly underrepresented in SDOs. Their unwitting exclusion is counterproductive as gender diversity brings a fuller range of experiences and the possibility of developing gender-responsive standards. Breaking it down further, since women are not a homogeneous group, representation and inclusion has been observed to also differ due to intersectional disadvantages.

This de facto exclusion of certain stakeholders' contributions is a significant concern, as ethnic and gender biases can creep into digital technology, particularly those utilizing AI and big data, and varied perspectives add greater relevance and credibility to standardization.

Furthermore, as a means to inform policymaking and national development strategies, standards should explicitly advocate for technology design and development processes that are informed by representative data sets, including sex-disaggregated data as well as qualitative data informing about the needs and experiences of different user groups, such as differently abled users. ISO/IEC Guide 71:2014 – Guide for addressing accessibility in standards suggests ways of determining user accessibility needs without providing specific solutions, noting that optimal solutions vary greatly depending on the specific users and contexts of use and that additional sector-related guides might need to be developed for specific product or service sectors. Equitable, high-quality access to new technologies and creating an enabling environment, which allows excluded or underserved persons to benefit from new technologies, while being a complex goal, should be supported through standardization. In addition to acknowledging and raising awareness on the necessary and unequally distributed infrastructural aspects, guidance on skills and capacity building aimed at addressing challenges associated with limited access and barriers to usage, affordability, digital literacy as well as digital skills should form an integral part of any standardization activity in the realm of digital transformation.

SUSTAINABILITY

Sustainability is not embedded in the digital transformation. Standardization is one area where the link needs to be more explicit between digital technology and its sustainability impacts. Standardization has a role to play in articulating the opportunities and threats from new technology for sustainability. For example, smart manufacturing crafted around circular economy ideas and smart agriculture potentially increases yields and reduces inputs protecting biodiversity and the environment. The absence of consideration of sustainability issues in the digital technology standardization space makes this principle important.

Noting the importance of sustainability in standard making, the London Declaration is a push from ISO to transform the approach to climate action and advance international work to attain net-zero goals. It emphasizes international standards' important role in assisting communities, organizations and industries in the transition to cleaner, renewable energy sources, and in helping to preserve biodiversity at the same time as opening up markets for innovations that address global environmental challenges. The London Declaration promises to embed key climate considerations into every new standard that is created. It will also retrospectively add these requirements to all existing standards as they are revised, a change on an unparalleled scale.

Emphasizing sustainability specifically in digital-related standard setting will encourage the usage of digital technologies to promote transformation towards an efficient, intensive and environmentally friendly development model, and enhance interoperability and cyclic utilization of digital hardware.

However, the incorporation of sustainability in standard making in the digital space is unsystematic and cursory. This principle is not systematically considered in the standard-making process despite the fact that digital technologies significantly influence the achievement of SDGs and standards have an important role in shaping achievement.

Given the far-reaching and long-term impact the digital transformation will have on people, their prosperity and the planet, digital technologies have a crucial role in delivering sustainability, therefore, aligning the digital transformation with the change needed for sustainability is essential.

SDOs and other standard-making organizations need to ensure that standards incorporate sustainability as a principle utilizing the SDGs and the 2030 Agenda to record impact and shape standards and digital technology outcomes. For example, ISO has published the standard ISO Guide 82:2019 giving guidance on how standards-makers can address sustainability in standards. The guide strongly encourages standards developers "to consider sustainability issues in their work at all stages in the standards development process. If sustainability issues have not been considered, this can be a valid reason to start the revision of a standard." ISO Guide 84:2020 – Guidelines for addressing climate change also references sustainability, noting that standards that take into consideration climate change can also directly or indirectly contribute to the achievement of sustainability. ISO also maps its standards impacts to specific SDGs.

INTEROPERABILITY

Interoperability is necessary for creating added value through the integration of compatible digital technologies. It is being given much attention in the standardization activities for the seven digital technologies addressed in this publication. Standards have a pivotal role in ensuring technology interoperability. In the context of digital transformation, standards development following the principle of interoperability should encourage the convergence of technical terms, criteria and methodologies not only in individual industry, but also on a broader cross-sector scale. They also should promote multi-stakeholder dialogue and coordination in digital-related standard setting to enhance standard harmonization and eliminate technological standard silos which create market access barriers and hinder competition.

Interoperability will enable digital transformation in organizations to be quicker, more affordable and effective. For example, harmonized standards in IoT allow technology to work together to enhance user experience. Compatibility between digitally transformed infrastructures will help instil long-term agility and economic efficiency in smart systems such as smart cities, infrastructure and manufacturing. Compatibility between digital technology and other frameworks such as the legal framework and DLT will help leverage the technology and ensure outcomes that benefit users and mitigate risk.

The successful implementation of pro-interoperability standards ensures compatibility and connectivity so that new technologies can be seamlessly adopted. By promoting interoperability in digital technologies, standards ensure market efficiencies, lubricate trade and increase efficiency and progress.

SAFETY AND SECURITY

Safety and security issues need to be a principal tenet on which standards are developed in the digital technology landscape because digital technology presents many challenges and risks. As more digital technologies interact with the physical world in the workplace and at home and play, people are exposed to physical and psychological safety and security risks.

4IR technologies also pose gender-differentiated safety and security concerns, particularly in terms of exposure to hazardous substances on reproductive health or the ergonomic design of physical technological devices. The legal framework has a raft of health and safety and product safety legislation applicable to new technologies. However, this legislation may not have the relevant elements to ensure emerging technologies integrate safety and security-by-design. For example, AI used in a self-driving vehicle must satisfy higher safety requirements than when AI optimizes a fully automated industrial process.

Standards and guidelines can specify how to prevent misuses, modifications and failures, and have procedures to enable humans to stay in control of security. The robustness of cybersecurity systems of digital technology that collect and utilize vast qualities of data is also a concern. Greater connectivity equates to more data that can be misused or attacked. For example, in 2015, hackers demonstrated that they could control a vehicle's braking and acceleration systems. Effective cybersecurity, therefore, is essential not just for cars but also for all connected digital technologies exposed to the threat of attack. Standardization has taken up the safety and security issue, supporting legislation by clearly focusing on the safety and cyber security risk in standards for digital technologies.

DATA PRIVACY

The digital transformation is driven by data. As people are increasingly interconnected and dependent on digital services, data privacy has become a horizontal and cross-sectoral issue that involves AI and big data, blockchain/DLT, IoT and UAS.

Data privacy governs how data is collected, shared and used. It is an area of data protection that concerns the proper handling of sensitive data, including, most notably, personal data, but also other confidential data, such as certain financial data and intellectual property data. Data privacy is not data security. Improper handling of privacy data may not lead to security concerns but can be classified as privacy intrusion.

Future standards directly or indirectly related to the collection, storage, exchange and usage of privacy data need to be developed by:

1) Highlighting the protection of privacy data as a priority;

2) Avoiding using technical terms, indicators, criteria and guidelines that may create loopholes for intrusion and abuse of privacy data; and

3) Providing guidelines to normalize the behaviour of data collectors, holders and users, and to empower original data owners by enhancing their awareness and visibility.

INTERNATIONAL COLLABORATION

As digital transformation creates both opportunities and challenges that transcend borders, international cooperation is a key dimension to make the most out of the digital transformation at local, national and international levels (see Text Box 7).

Text Box 7 – Cooperation and participation in Africa and South America

The African Organisation for Standardisation (ARSO) signed a memorandum of understanding (MoU) with ISO in 2021, aiming to strengthen the cooperation between the two organizations with a critical feature to improve the ability of ARSO members to participate in international standardization activities effectively.

The Pan American Standards Commission (COPANT) highlighted finding experts who were also fluent in English a particular issue for South American members of their organization. The organization has enhanced investment in ICT and IT tools during the pandemic, however, the lack of these resources persists and can inhibit active participation in standardization.

Highlighting international collaboration in standards development will facilitate coordination and harmonization of regional and global digital markets and promote more effective regulatory response. More specifically, it can help to:

1. Lower technical barriers for international flow of digital goods and services and build a more integrated regional and global digital market which can help countries fully tap into their digital potential;
2. Mitigate the risk of transnational cybercrime, privacy intrusion and intellectual property violation; and
3. Address national security concerns on data security, communication technology reliability and key infrastructure resilience.

To promote international collaboration, it is essential for international organizations to strengthen their roles in trust building and partnership mobilizing, actively engaging with their members and effectively leveraging collective efforts in international standards development and capacity building. National standards bodies need to consider applying international standards before developing their own set or referring to them as recognized equivalents.

PART 5: FUTURE

REFLECTIONS ON THE FUTURE OF STANDARDS IN DIGITAL TRANSFORMATION GOVERNANCE

Digital technologies will forever transform systems changing how societies live, work and play. They possess transformative potential for developing countries and for the achievement of the SDGs, on the condition that dedicated access mechanisms are created and implemented internationally and that developing countries are not excluded from the standard-setting process. While these emerging technologies have the potential to drive enormous social breakthroughs and economic value, they also have the potential for unintended consequences and adverse effects for people, their prosperity and the planet.

This is a call to action as society must understand the risks and rewards of the digital transformation. Standards-makers need to leverage the role of standards to ensure that digital technologies remain human-centered and aligned to the goals of sustainability, providing everyone in society with equitable access and unbiased participation.

Progress in the innovation and development of digital technologies and digital transformation is creating a fast-moving environment and is unstoppable. The regulatory and policy frameworks develop appropriate governance rules for technology, however, this evolving framework has limitations such as being primarily nation bound and time-consuming. Standards have an important role in this framework, being transnational, multi-stakeholder driven, speedy to develop and responsive to user needs.

Standards have the potential to contribute to digital transformation governance. In order to unlock this potential, the following aspects should be considered:

» The scope of impacts of the digital technologies shaping the 4IR vary. A robust strategy is required to understand the implications of current and future technologies and to shape the digital transformation towards people, their needs and the planet.

» Standards developers worldwide need to work as a community to provide objectivity, credibility, and transparency in their standards work and to ensure their output is understandable and usable.

» There is a need for collaboration and technical cooperation between standards developers of all types to ensure the most comprehensive, high-quality, and up-to-date selection of standards for digital technologies and a high level of convergence is produced. This includes creating an inclusive environment and allowing equal and appropriate representation of all relevant stakeholders, which is paramount in standardization.

» Sustainability is an area where the link must be made more evident in standards developed for digital technology. In doing so, the impacts of digital technologies can be taken into account and their transformative capabilities can be better leveraged to strengthen all SDG pillars—people, planet, prosperity, partnership and peace.

» Standardization, guided by the seven principles of trustworthiness, interoperability, safety and security, data privacy, inclusiveness, sustainability and international collaboration, can support people, prosperity and the well-being of the planet. Building on strong partnerships, the standards community can ultimately contribute to good governance.

As this decade is critical for the planet and its people, this publication is a call to action to all stakeholders in the development of regulations and standards to consider the outlined principles in their work in order to leverage the opportunities offered by digital technologies and thereby accelerate prosperity for all.

Department of Digitalization, Technology and Innovation (DTI)
Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 26026-0

www.unido.org

dti@unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION