Rapidly Emerging Frontier Technologies and Emerging Science Issues for SDGs

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Abstract

Engaging the fast-emerging new technological developments in IT and ITES along with small electromechanical devices in all sectors of the economy – agriculture, manufacturing and services- we are empowered to carry out our missions with a high order of reliability, safety and efficiency – all leading to a sustainable mode of transactions in every field. Under guided policy at the national and international level, they can considerably reduce the environmental burden on the planet and nature on account of human interventions. The kind of disruptions happening around in the present times – markets, innovations, connectivity, computing power- are unprecedented than those that happened anytime in past history. This note , besides listing and defining these technologies and their implications suggests areas where policy-guided approaches are necessary for achieving the SDGs.

A brief overview of the various emerging technologies having a direct bearing on the achievement of sustainable development goals is given hereunder as a prelude to discussing the policy-related issues for their effective application in relevant areas.

Data analytics

Every activity generates raw data. Data analytics enable us to take raw and uncover patterns to extract valuable insights on the underlying information which is used for decision making. Performance monitoring of systems and equipment, financial planning, budgeting and forecasting etc are done effortlessly and help businesses drive faster decision making and achieve more accurate results.

There are four primary types of data analytics: descriptive, diagnostic, predictive and prescriptive analytics. Descriptive analytics analyzes past data to see trends and patterns to understand what happened over a period of time. Diagnostic analytics explores why things happened in a particular manner at a given point in time. This generally occurs in identifying anomalies and statistically finding relationships and trends that explain these anomalies. Predictive analytics gives a prediction of what would happen in the future. Here historical data is used to identify trends and determine if they are likely to recur. Prescriptive analytics suggests remedial actions to be undertaken in a given situation. By using insights from predictive analytics, data-driven decisions can be made. This allows us to make informed decisions in the face of uncertainty.

India developed Aadhar, a comprehensive directory with a biometric ID of over 1.3 billion people and demonstrated to the world that a digital database can support and enrich the quality of life of the people to transform the country to a digital economy. The use of mobile internet and the smartphone enabled quick and the reliable banking, ensured hassle free e-commerce and revolutionised public health care and modernised agriculture through digitalization of related services. An array of startups, the new generation entrepreneurs opened up tremendous opportunities in several sectors of the national economy and also created new markets.The new innovations and technological capabilities along with digital devices and smart applications, refinement of the tax administration, underwriting of creditors, agriculture information systems- weather, cropping, sowing, irrigation and harvesting- have all became easy. So also increasing the efficiency of operations and quality of products from MSMEs and delivery of government services to the public.

Internet of Things (IoT)

The Internet of Things is developed on the concept of combining computers, sensors, and networks to monitor and control devices. Here network connectivity and computing capability extend to objects, sensors and everyday items allowing these devices to generate, exchange and consume data with minimal human intervention. In the current situation confluence of several technology market trends, is bringing the Internet of Things closer to widespread reality. These include universal connectivity, widespread adoption of IP-based networking, computing economics, miniaturization, advances in data analytics, and the rise of cloud computing. It enables communities to usher in a revolutionary, fully interconnected "smart" world, with relationships between objects and their environment and objects and people becoming more tightly intertwined. The prospect of the Internet of Things as a ubiquitous array of devices bound to the Internet might fundamentally change how people think about what it means to be "online". Four common communications models include Device-to-Device, Device-to-Cloud, Device-to Gateway, and Back-End Data-Sharing. These models highlight the flexibility in the ways that IoT devices can connect and provide value to the user. Five key IoT issue areas are security; privacy; interoperability and standards; legal, regulatory, and rights; and emerging economies and development.

The key stakeholders in the Internet of things initiatives are the citizens, the government and the industry. Initially policies are required for promotion of IoT and selection of e essential domains and identify specific data requirements. Later those related to participation and collaboration among the stakeholders will be required.

Cloud computing

Cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale. Users pay only for cloud services being used, helping lower operating costs, run infrastructure more efficiently and scale as business needs change. It is Cost-effective in the sense that in this mode, the capital expense towards hardware and software and setting up and running on-site datacentres, uninterrupted power supply and the IT experts for managing the infrastructure. The services are provided self service and on demand, so even vast amounts of computing resources can be provisioned in minutes giving businesses a lot of flexibility and taking the pressure off capacity planning. It operates on a global scale such that computing power, storage, bandwidth are made available right when it is needed and from the right location. Cloud computing eliminates racking and stacking hardware setup, software patching, and other time-consuming IT management chores leading to increased productivity and enable focussing on important business goals. Here the global network of datacentres is regularly upgraded to the latest generation of fast and efficient computing hardware always to perform better. Besides it has a reliability of a high order enables data backup, disaster recovery and business continuity easier and less expensive and offer a broad set of policies, technologies and controls that strengthen security posture overall, helping protect data, apps and infrastructure from potential threats.

Most cloud computing services fall into four broad categories: infrastructure as a service (IaaS- renting IT infrastructure), platform as a service (PaaS- on-demand environment for developing, testing, delivering and managing software applications), serverless computing (building app functionality without spending time continually managing the servers and infrastructure required to do so) and software as a service (SaaS- delivering software applications over the Internet,).

Robotics

A robot is a programmable machine that imitates the actions or appearance of an intelligent creature, usually a human. Robotic process automation help automate tedious, time-consuming tasks and error-prone manual processes and thus free up operators to focus on more value added work. Robots were originally built to handle monotonous tasks but have since expanded well beyond their initial uses to perform tasks like fighting fires, cleaning homes and assisting with incredibly intricate surgeries. Each robot has a differing level of autonomy, ranging from human-controlled robots that carry out tasks that a human has full control over to fully-autonomous bots that perform tasks without any external influences. All robots vary in design, functionality and degree of autonomy. It includes pre-programmed robots operating in a controlled environment where they do simple, monotonous tasks. Humanoid robots mimic human behaviour. Autonomous robots operate independently of human operators. Teleoperated robots are semi-autonomous bots that use a wireless network to enable human control from a safe distance and Augmenting robots either enhance current human capabilities or replace the capabilities a human may have lost.

Artificial Intelligence (AI)

It is the science and engineering of making intelligent machines, with computer programs. Here computers are used to understand human intelligence. Artificial intelligence leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind. Thus artificial intelligence combines computer science and robust datasets, to enable problem-solving. It also encompasses sub-fields of machine learning and deep learning, which are frequently mentioned in conjunction with artificial intelligence. There are numerous, real-world applications of AI systems today. Some of the most common examples include speech recognition, image recognition through computer vision, customer servicing, online stock trading etc.

Industrial Automation

Modern smart factories which normally operate beyond the economy of scale, typically use a variety of advanced equipment and devices that are required to function at an optimal level and in perfect coordination with little supervision. These devices generate so much data and therefore it is extremely difficult for plant operators to always oversee and manage each of the production lines. A state-of-the-art factory unit thus needs an advanced system to manage the facility to improve efficiency, keep it stable, operate safely and make maintenance easier. Here is the relevance for advanced industrial automation. The specific challenges include inability to decipher information from multiple, diverse and vast range of devices and equipment, predict imminent failures of systems and manage abnormal system behaviour. The remedy lies in online device and equipment management interface accessible from anywhere, continuous monitoring of storage devices and other equipment and effective and timely communications. Such automation systems are capable of drastically streamlining factory management and reduce costs incurred by maintenance and planning work. Operators also receive timely alerts about potential devices and equipment which facilitate timely repairs and replacements to improve system uptime. One of the core concepts of modern automation is augmented reality; in other words, creating virtual versions of devices, machines and vehicles.

3D Printing

3D printing or additive manufacturing is a process of making solid objects from a digital file with the help of printer type building device from the specific material of construction. The 3D printed object is created through an additive processes by laying down successive layers of material until the object is fully built up.3D printing is the opposite of subtractive manufacturing in which material is removed by milling or machining from the material of construction so that the final product is obtained.3D printing enables to produce complex shapes using less material than traditional manufacturing methods. The application areas of 3D printed products are still expanding. Presently it is used effectively in the design and prototyping and industrial manufacturing, education and learning, medical applications in drugs and implants, construction industry, and artifacts and jewellery. Efficient utilization of material resources, conservation and avoidance of waste are the contributory factors towards sustainable manufacturing.

Blockchain

A blockchain is a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems and records information in a way that makes it impossible to change, hack, or cheat the system. A typical database stores information whereas blockchains store data in blocks that are then chained together. As new data comes in it is entered into a fresh block. Once the block is filled with data it is chained onto the previous block, which makes the data chained together in chronological order. An asset can be tangible (a house, car, cash, land) or intangible (intellectual property, patents, copyrights, branding). Virtually anything of value can be tracked and traded on a blockchain network, reducing risk and cutting costs for all involved. It is ideal for delivering information because it provides immediate, shared and completely transparent information stored on an immutable ledger that can be accessed only by permitted network members. It can track orders, payments, accounts, production and avoid paperwork. And because members share a single view of the truth, you can see all details of a transaction end-to-end, giving you greater confidence. This digital ledger technology can simplify the complex and risky paperwork used for property records or in currency systems and ensure transparency all throughout. With the decline of the use of cash especially during pandemic times, more governments are adopting digital currency systems which work on the above concept.

Machine Learning

Machine learning is a data analytics technique that uses artificial intelligence, statistical methods, and algorithms to replicate the way humans think and act with the help of computers. It is capable of analysing classified data and predictions, unearthing underlying insights and learning from past experience, and improving performance. Machine learning algorithms use computational methods to learn information directly from data without relying on predetermined equations or models. It is used every day to make critical decisions in medical diagnosis, stock trading, energy load forecasting, maintenance prediction, and language processing through voice recognition and image processing using computer vision, etc. It is through a high order of optimization of resources including energy and manpower that ML contributes towards the advancement of SDGs.

Biotechnology

Present-day developments in biotechnologies have immense potential to contribute towards sustainability. Increasing food production and combating nutrient deficiency, use of renewable raw materials for production of energy, prevention of pollution at source and bioremediation of contaminated sites have become conventional application areas. Environmental biotechnology has revolutionized pollution abatement in chemical processing through conservation and promoting optimal use of inputs so as to retain an adequate resource base for future generations. Recovery of resources which would be lost to the environment and its recycling, safe disposal of hazardous-waste are other avenues where BT play a significant role leading to overall sustainability. Genetic modification and the development of tools in manipulating genetic frameworks have empowered the cell factories to reliably produce recombinant protein through the bio-route. Advances in molecular biology, gene technologies and artificial photosynthesis have gained paramount significance in fostering sustainable development goals, limiting ecological and social burden and easing economic inequality.

Nanomaterials

Nanotechnology as a concept has been revealed by scientists for over five decades and now it has become mature enough to contribute in several fields of human activity. It includes agriculture, healthcare, engineering, material science, ICT, water purification, chemical synthesis, and so on. In these fields, Nanotechnology enables to dramatically improve the efficiency of energy use and promote conservation, avoid pollution and clean up the environment, effect quick drug delivery in the treatment of diseases, reduce wastage in high volume manufacturing and achieve better nutrient administration in farming by drastically reducing excessive the application of mineral fertilizers. All the above contribute to the direct achievement of the SDGs and therefore, need to be pursued and made use of effectively. Products of nanotechnologies and their handling arise major challenges and issues with regards of potential risks on account of its toxic nature and related ethical considerations. If used under the governance of a prudent policy regime, this cutting edge technology offers the much-needed technology solution for reducing the environmental burden of the present times.

Policy recommendations

The socio-economic and environmental impacts of the above technologies pose serious development-related challenges for societies and institutions. This can be resolved only through policy interventions at the appropriate level. With regard to data science, scope for policy-related interface with the government for its unstinted use and productive use is enormous. Data-based policies of the government will reduce uncertainty in its formulation and therefore will be efficient and effective. Policy directions will also be required for sharing of Government data that is considered transparent, accountable and responsible to citizens and researchers. More and more governments are already making use of data science in their governance. This indicates that data scientists will have to play increasingly important roles, along with researchers and analysts, in the formulation of public policies.

One of the major challenges facing the development of these technologies is the lack of appropriate standards in some areas. Governments shall encourage and support the development of open interoperable standards for business deals by coordinating with different standards institutes. Policy formulations in this area shall look into standardization and certification at the international level on the lines of ISO standards. Renewed standards for material conservation and avoidance of waste may have to be developed.

Policymakers themselves have to be educated in the working of these technology projects for govt service delivery, education, research and developing new tools, methodologies, guidelines etc intended for their better use. Social impacts such as reluctance for adoption of new technologies, fear of job/skill loses, exclusivity, cost and threat of digital divide may also be addressed through policy enactments. Social impact assessment of promoting the use of the internet of things (IoT) by industry, the public sector, and consumers are being undertaken in different parts of the world. Licensing of spectrum for WiFi use, marking of spectrum bands for specific sectors, capacity development for domestic and export markets are also to be guided by specific policies. Countries shall develop policies for effective use of these technologies in public interest in areas such as farming and agriculture, health and disease prevention, maintaining water quality, mitigation of natural disasters, sustainable transportation, state and cyber security, supply chain management, civic administration of smart cities, utilities planning and promotion of waste elimination and management, etc.

Biotechnology and Nanotechnology deal with tampering the basic building blocks at the molecular level and therefore need a very stringent and transparent policy regime to guide its experimentation and usage in real-life situations.

Policymakers may use law, market, social norms, and technology as tools and focus on topics such as liability, security, privacy, and autonomy to bring out guidelines for hassle-free use of these technologies for overall sustainable development. It shall also take care of the requirements of system security and robustness, resilience, consumer protection, sustainability, and human and civil rights.

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