Study of Various General-Purpose Technologies and Their Comparison Towards Developing Sustainable Society

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ABSTRACT

Technology is used in many ways to solve many complicated challenges in the society. Certain technologies have grown and expanded their branches to many areas and sectors of practice in such a way that they have been designated as General-Purpose Technologies. General Purpose Technologies' (GPT) are characterized by pervasiveness where they have an inherent potential for technical improvements, and innovation complementarities, meaning that the productivity through research and development in related sectors increases due to the consequence of innovative applications through such general-purpose technologies. Thus, as general-purpose technologies progress, they spread throughout the economy, eventually bringing about generalized productivity gains. Examples include the steam engine, railroad, interchangeable parts, electricity, electronics, materialhandling, mechanization, control theory (automation), the automobile, the computer, the Internet, and nanotechnology. In this paper, we have identified, analysed, and compared Information Communication and Computation Technology (ICCT), and Nanotechnology (NT) as two most important general-purpose technologies due to their abilities to solve both basic problems and advanced need of the society. The paper also contains a conceptual and predictive proposal on how various general-purpose technologies including ICCT and NT are potentially contributing towards creating a techno-society and based on further progress and spread of such technologies to every dimension of human life to reach the ultimate level of civilization in or around this earth. The analysis finally leads to the development of the concept of 'Universal Technology' model.

Keywords: General purpose technologies, Information Communication and Computation Technology (ICCT), Nanotechnology (NT), Technologies for social development, Universal technology.

1. INTRODUCTION :

Technology by itself is an application of science is used in many ways to solve many complicated challenges in the society to make human life comfortable and enjoyable. Certain technologies have grown and expanded their branches to many areas and sectors of practice in such a way that they have been designated as General-Purpose Technologies. Such technologies are identified and used by many branches of engineering to solve or simplify the problems of those fields. General Purpose Technologies' (GPT) are characterized by pervasiveness where they have an inherent potential for technical improvements, and innovation complementarities, meaning that through research and development the productivity in sub-sectors increases as a consequence of such innovation in the GPT [1].Many of the killer applications invented in the history are though costly and less productive initially, emerged eventually as General Purpose Technologies. Examples include the steam engine, railroad, interchangeable parts, electricity, semiconductor electronics, material handling, mechanization, control theory (automation), the automobile,

the computer, the Internet, Information Communication and Computation Technology (ICCT), and Nanotechnology (NT). The major stakeholders of Information Communication and Computation Technology (ICCT) as general purpose technology are Analytics and Big data, Cloud Technology, Artificial Intelligence, Internet of Things (IoT), Digital Marketing, 3D Printing, Virtual Reality and optical computing.

The major stakeholders of Nanotechnology as general-purpose technology are Agriculture with improved and sustained yield, Universal drinking water system, Universal Renewable energy system, Optical computation, Embedded intelligence, Chameleon chips, Flying cars, Space travel, Nanomedicine, and anticipated Immortality.

Table 1 : Killer Applications and their transformation into GPT

S. No.	Killer Technology	Spillover Effect	Era
1	Wheel	Mechanization	4000-3000 BC
2	Bronze	Tools & Weapons	2800 BC
3	Printing	Knowledge Economy	16th Century
4	Steam Engine	Industrial Revolution	18th Century
5	Electricity	Power generation & Usage	19th Century
6	Automobile	Long distance commuting & Transportation	20th Century
7	Airplane	International Travel & Transportation	20th Century
8	Telephone	Distance communication	20th Century
9	Television	Video communication	20th Century
10	Computer	Data Processing	20th Century
11	Internet	Data & Information Communication, E-business	20th Century
12	Mobile Communication	Ubiquitous communication	20Th Century
13	Biotechnology	Bio-engineering, Gene Therapy,	20th Century
14	Information Communication & Computation Technology (ICCT)	Ubiquitous computing & Communication	21st Century
15	Nanotechnology (NT)	Solutions to nutritious food, drinking water, renewable energy, Nanomedicine& Therapy	21st Century
16	Artificial Intelligence (AI)	Total automation	21st Century

As listed in table 1, some of the killer applications transformed into GPT's and many of them are making an impact only in one or two related areas and replaced by other innovative technologies or die-down eventually. In this paper, we have identified and analysed two killer applications and compared Information Communication and Computation Technology (ICCT), and Nanotechnology (NT) as two most important general-purpose technologies due to their abilities to solve both basic problems and advanced need of the society. We also studied the similarities and differences between these two GPT's in terms of their specially identified characteristics of Pervasiveness, Improvement, and Innovation spawning abilities. The paper also contains a conceptual and predictive proposal on how various general-purpose technologies including ICCT and NT are potentially contributing towards creating a techno-society and based on further progress and spread of such technologies to every dimension of human life to reach the ultimate level of civilization in or around this earth.

2. GENERAL PURPOSE TECHNOLOGIES :

A general-purpose technology or GPT is a term coined to describe a new method of producing and inventing that is important enough to have a protracted aggregate impact. Electricity and information technology (IT) probably are the two most important GPTs till 20th century. A GPT can be a product, a process, technology or an organisational system.

Whole eras of technical progress and growth appear to be driven by a few 'General Purpose Technologies' (GPT's), such as the steam engine, the electric motor, and semiconductors. GPT's are characterized by pervasiveness to many sectors, inherent potential for technical improvements, and innovation complementarities to many applications, giving rise to increasing scale of operation. A notable writer Ruttan[2] identified the development of six general-purpose technologies:

- Interchangeable parts and mass production
- Military and commercial aircraft
- Nuclear energy
- Computers and semi-conductors
- The Internet
- The space industries

Based on his reading of the histories of these technologies, Ruttan finds that military and defense-related procurement has been a major source of technology development. He believes that the current technological landscape would look very different in the absence of military and defense-related contributions to commercial technology development. However, from his research, Ruttan determines that commercial technology development would have occurred in the absence of military procurement but more slowly, e.g., the aircraft, computer, and Internet industries. He cites nuclear power as an example of a general-purpose technology that would not have developed in the absence of military and defense-related procurement [2].

Economist Richard Lipsey and Kenneth Carlaw [3] suggested that there have only been 24 technologies in history that have been identified as true GPTs. They define a transforming GPT follows four criteria which are listed below:

(1) GPT is a single, recognisable generic technology.

(2) Initially GPT has much scope for improvement but comes to be widely used across the economy.

(3) GPT has many different uses in many areas to solve problems or to provide comfortability.

(4) GPT creates many spill over effects to spread its base to many sectors.

3. HOW GENERAL PURPOSE TECHNOLOGIES ARE DIFFERENT :

General purpose technologies have the potential to reshape the economy of the world and boost productivity across all sectors and industries. Such transformations are far more than simple technical innovation, or anew discovery. However, such technologies often require a wholesale remaking of infrastructure environments, of business models, and of cultural norms. There are three fundamental features of GPTs that differentiate them from other technologies which are (1) Pervasiveness – The GPT should spread to most sectors. (2) Improvement – The GPT should get better over

time and, hence, should keep lowering the costs of its users. (3) Innovation spawning – The GPT should support to invent and produce new products or processes. Most technologies possess each of these characteristics to some degree, and thus a GPT cannot differ qualitatively from these other technologies [1].

4. ICCT & NT AS GENERAL-PURPOSE TECHNOLOGIES & SYSTEMS :

4.1 ICCT as GPT :

It is observed that Information Communication and Computation Technology (ICCT) is showing all the three characteristics of GPT. In the 21st century, ICCT is grown and spread its roots to all industries and industry sectors from A to Z due to its pervasiveness property as shown in Table 2. The Improvement and Innovation spawning properties of Information Communication and Computation Technology (ICCT) as general purpose technology are created major stake holding areas including Big data and business Analytics, Cloud Technology, Artificial Intelligence, Internet of Things (IoT), Digital Marketing, 3D Printing, Virtual Reality, and optical computing.

(i) Big data and business Analytics:

The emerging subfield of ICCT named big data and business analytics focus on handling huge amount of data continuously generated in any business or data capturing process and analyses it using various quantitative analytical techniques and mathematical models to study the pattern and descriptive information, predictive information, and prescriptive information for supporting the decision makers to take optimum decisions to the problems related to future aspects of the business. Predictive analytics in various functional areas like Marketing analytics, Retail Analytics (Customer Analytics / Supply Chain Analytics), Pricing Analytics, Financial analytics, Social media analytics, sports analytics, and Healthcare analytics are finding importance in the business environment for effective decision making. Further Prescriptive Analytics foroptimizing the decisions with multiple objectives / portfolio analytics, optimizing complex decisions / salesforce analytics, and Retail Analytics etc are also have futuristic impact on effective business decisions [4-7].

(ii) Cloud Technology:

Cloud computing is one of the advances in computer technology and is uses information communication technology as well. Due to the ubiquity of cloud computing facility with flexibility in scaling it has become an important topic of research and provides the value for computing processes in the business. The cloud computing model offers so-called Business Intelligence (BI) for any kind of business decisions via the Internet. Using cloud computing model, one can offer a rented hardware as well as software to process the data online. Thus, cloud computing model has three variations as Software as a Service (SaaS), Infrastructure-as-a-Service (IaaS) and Platform-as-a-Service (PaaS) to provide ubiquitous computing service solutions to the business. The cloud computing solution to any business will allow companies to reduce their investment cost and maintenance cost for without compromising to have access to BI solution which will give the business an edge on their competition [8-15]. Could computing is subfield of the Information Communication and Computation Technology (ICCT).

(iii) Artificial Intelligence :

Artificial intelligence (AI) is an area of computer science which focus on the creation of intelligent machines that makes decisions like human beings. The main functions of artificial intelligence machines are to recognize the environment such as speech recognition, Learning, Planning, Problem solving, and hence decision making. Artificial intelligence machine mimics cognitive functions of human beings associated with other human minds, such as learning & memorising and decision making for problem solving. ICCT has created a platform for AI to be introduced and developed for adding intelligent thinking components in electronic systems used in any industrial sectors [16].

(iv) Internet of Things (IoT) :

It is a network of various electronic, computing, and optical devices/objects including human beings connected virtually by means of internet

or intranet for enabling them to send and receive data and information. These objects are provided with unique identifiers (UIDs) and are capable to transfer data and information over a network without requiring human-to-human or human-to-computer interaction by using IOT technology. Such a connection of physical things/objects to the Internet makes it possible to access remote sensor data and to control the physical world from a distance. The mash-up of captured data with data retrieved from other sources, eg, with data that is contained in the Web, gives rise to new synergistic services that go beyond the services that can be provided by an isolated embedded system [17]. Internet-of-Things (IoT) is not in any new disruptive technology but is the pervasive deployment and innovation of ICCT.

(v) Digital Marketing :

ICCT created a new business model called E-business/ M-business model. This model consists of ubiquitous selling proposition. Digital marketing is the marketing of products or services using digital technologies as per such new business model using mainly on the Internet, but also including mobile phones, display advertising, and any other digital medium. At a high level, digital marketing refers to advertising delivered through digital channels such as search engines, websites, social media, email, and mobile apps. Digital marketing is emerged as an essential future marketing activity using ICCT general purpose technology [18].

(vi) 3D Printing :

3D printing is an ICCT application where various materials are joined or solidified using various processes under the control of computer to create a three-dimensional object. In 3D printing, an object is created by laying down successive layers of material until the object is created. 3D printing can be divided into metal, fabrics, bio and a whole host of other industries with many applications in many industries worldwide.3D printing is a variant of ICCT general purpose technology and has wide scope in various industrial automation and home automation processes. 3D printing comprises of many other technologies along with ICCT. Some of the 3D printers make use of nanomaterials and nanocomposites [19].

(vii) Virtual Reality :

Virtual reality is an artificial environment that is created with the help of computer-based software and presented to the user in such a way that the user suspends belief and accepts it as a real environment. On a computer, virtual reality is primarily experienced through two of the five senses: sight and sound. Currently, the virtual reality is mainly developed and used in simulated training and education as well as the simulated game environment. But it may further find its applications in many other areas including business as augmented reality and may enter the group of general purpose technology [20].

(viii) Optical computing:

High speed computers based on optical signal switching and optical signal processing are expected to breakthrough with their full potentials and capabilities using optical logic gates and flip-flops fabricated by nanocomposites are expected to breakthrough in this century. High speed computation and data storage using nanotechnology based optical computers are going to revolutionize the entire computer industry. Optical computation is joining both general purpose technologies of Nanotechnology and ICCT through the processes of design & production as well as operation & applications respectively [21].

Table 2 : Industries and Industry sectors which use and benefit from ICCT

S. No.	Industries	Industry Sectors/Segments	ICCT Applications
1	Agricultural & Allied Industries	Agricultural products, Forestry & logging, Fishery.	Remote sensing using satellite technologies, Geographical information systems, Agronomy and soil sciences, Weather prediction& forecasting etc.

2	Auto components	Engine &Drive Transmission Parts, Suspension & Braking Parts, Electricals, Body and Chassis Parts, Equipment etc.	Product Lifecycle Management, Research & Development Manufacturing automation Sales automation Post sales solution
3	Automobiles	Commercial vehicles, Passenger cars, Three & two-wheelers.	Use of IT in new vehicle design, systems control, manufacturing, sourcing, and marketing.
4	Aviation	Civil aviation, Military aviation	Airport operations, Air-cargo operations, Airline management, Air-ticketing, Security etc.
5	Banking& Insurance	Public Banking Private banking International banking Life insurance General insurance	E-banking, Online banking, Online and mobile services, ERP and networking, Transactional services, ATM management etc.
6	Cement	Cement Production, Cement transportation	Energy efficiency in production Transportation management, Quality monitoring etc.
7	Consumer Durables	Consumer electronics (brown goods) Consumer appliances (white goods)	Production automation, Supply chain management, Online sales, Online payment, Online customer support, etc.
8	E-Commerce	E-procurement E-marketing E-payment	E-cart, Internet, Secured online payment, Customer support, E-advertisement
9	Education & Training	Education, Training	Online education, Online training, E-gadgets, online evaluation etc.
10	Engineering & Capital Goods	Transport equipment, Capital goods, other machinery/equipment and light engineering products such as castings, forgings and fasteners.	Made to order, Order processing, Supply chain management, Quality control systems Online customer management, ERP etc.
11	Financial Services	Credit unions, Banks, Credit-card companies, Insurance companies, accountancy companies, Consumer-finance companies, stock brokerages, Investment funds, etc.	Operational automation, Online transactions, Online services, electronic business, etc.
12	FMCG	Packaged foods, Beverages, Toiletries, Over-the-counter drugs, Other consumables.	Retail management Supply chain management E-distribution Business to Business E-Commerce
13	Healthcare	Hospitals, Medical devices, Clinical trials, Outsourcing, Telemedicine, Medical	Communication, Computerization of medical records, Networking of various departments in

		tourism, Health insurance and Medical equipment	a hospital, Tele-medicine services
14	Infrastructure	Transportation, Communication, Sewage, Water and electric systems	Basic Communication and Computation
15	IT & ITES	E-Communication Cloud computing, Mobile applications E-services E-Business	Business Automation Business process outsourcing Resource sharing Ubiquitous business
16	Manufacturing	Raw materials, Food manufacturing, Textiles	Automated procurement Quality control Online marketing
17	Media & Environment	Print media, Radio, TV media, Social media, and film,	Digital techniques Online media Internet based social networks etc
18	Pharmaceuticals	Pharmacy Drug production Clinical practice	Online pharmacy Drug information Clinical information sharing
19	Ports	Ports Terminal management Shipping	Automation of all activities
20	Power	Coal Hydro Renewable energy	Automation of all activities Control of wastage
21	Railways	Goods trains Passenger trains Railways Infrastructure	Online booking E-communication Safety
22	Real Estate	Residential sector Commercial sector	Tele communication Entertainment
23	Retail	Convenience Stores, Specialty Stores, Department Stores, Supermarkets, Hypermarkets, Discount Stores, Multichannel Stores.	Communication Online transactions Online store Online payment E-inventory etc.
24	Science & Technology	Research & Development Emerging technologies Bio-technology Space technology Nanotechnology etc.	Back ground support Online Journals Research data Space data & Travel Design 7 development
25	Services	Warehousing and truck transportation services, Information sector services, Commodities, Securities and other investment services	Process Automation Customer service Information E-Business models Online payment
26	Telecommunications	Telecom equipment (the largest), Telecom services (next largest),	Electronic signal Radiofrequency signal Wireless data

		Wireless communication.	Video and audio communication
27	Tourism & Hospitality	Food and beverages, Travel and Tourism, Lodging, Recreation.	Geographical Positioning systems, Online booking Audio & Video recording & Processing.

ICCT has made a major impact due its associated new business models called e-business model and m-business models. These business models provided both business organizations and customers to use ubiquitous concept of selling and buying the goods and services from anywhere, anytime and any amount of time. The business model developed using ICCT general purpose technology is very close to ideal business model [22-24].

4.2 Nanotechnology as GPT :

The major stakeholders of Nanotechnology as general-purpose technology are Universal drinking water system, Universal Renewable energy system, Optical computation, Embedded intelligence, Chameleon chips, Flying cars, Space travel, and anticipated Immortality [25-26].

(i) Nanotechnology treated Seeds for Innovations in Agriculture :NT solutions in agriculture reduce applications of plant protection products, minimize nutrient losses in fertilization, and increase agricultural yields through optimized nutrient management. It also provides nanotech-based tools to detect diseases in a rapid manner, improve the ability of plants to absorb nutrients and promote the molecular treatment of diseases. Use of nano-sensors supports the use of precision farming methodologies to a multifold increase of crop yield. Nanotech-enabled “smart” devices can preventive and warn to choose diseased plant even before they detected by the farmers and simultaneously provide remedial measures. These nanotech systems can also be used to monitor the delivery of chemicals [27].

(ii) Universal drinking water system :Nanotechnology has shown opportunity in solving another fundamental problem of many people of the world which is the scarcity of drinking water. Though we have abundant water in the sea, it is non-potable and hence not useful for drinking and irrigation. Nanotechnology filters are promising solutions to filter soluble and insoluble impurities mixed from the water both in small scale and large scale. This innovation leads to scalable universal drinking water system. Nanotechnology will provide a solution for this challenge of providing abundant drinking water through inexpensive methods of water purification by detection of the molecular level of contaminants, and improved nanomembrane based filtration systems. This helps the conversion of seawater to drinking water at a very low cost [28].

(iii) Automobiles :Automobiles is one of the largest industries in the world. Automobile industry is trying to make a breakthrough in improving the efficiency, durability, and cost of vehicles using nanotechnology solutions along with decreasing the pollution by using hydrogen fuel or electric engines. The major expected impact of nanotechnology innovations on Automobile sector in order to solve the problems in automobile efficiency, durability, cost, and environmental pollution to produce electric/pollution free vehicles with nanotechnology-based auto-components, auto-engines, auto-tyres, auto-electronics, auto-seat materials, auto-bodies, aeroplanes, space crafts, and rockets [29].

(iv) Renewable energy system :The nanotechnology impact on seven areas of energy sector including solar energy, wind energy, nuclear energy, oil-fuel based energy, artificial photosynthesis, energy storage and effective energy management to promote nanotechnology-based energy as ubiquitous energy are discussed and reviewed. The paper includes possible innovations and research opportunities in nano-modified solar cells, Nano-influenced Fuel storage cells, and nanotech based artificial photosynthesis [30-32].

(v) Optical computation :High speed computers based on optical signal switching and optical signal processing are expected to breakthrough

with their full potentials and capabilities using optical logic gates and flip-flops fabricated by nanocomposites are expected to breakthrough in this century. High speed computation and data storage using nanotechnology based optical computers are going to revolutionize the entire computer industry. Optical computation is joining both general purpose technologies of Nanotechnology and ICCT through the processes of design & production as well as operation & applications respectively.

(vi) Embedded intelligence :Embedded intelligence is a technique to modify the ability of a product, process or service to reflect on its own operational performance, usage load, or in relation to the end-user or environment in terms of satisfactory experience and smart improvement. This improvement through self-reflection, facilitated by information collected by sensors and processed locally or remotely, must be considered from the design stage such as to improve the product features, enhance the product lifetime and performance, increase the quality of process or service delivery, or ensure customer satisfaction and market acceptance [33-36]. Embedded intelligence aims at delivering smarter products, systems or services to industry through their integration and purposeful use for a given application. Embedded intelligence (EI) system/service application contains various components/ processes which include design for EI, intelligent software, packaging & interconnect, manufacturing solutions and/or system services. Nanotechnology supports the integration of embedded processors with sensors, intelligence, wireless connectivity and other components with high level operating systems, middleware and system integration services.

(vii) Chameleon chips :A chameleon chip is a self-configurable electronic or optical circuit to modify the output signal characteristics as per the system requirements. It has an erasable hardware configuration. It is also possible to rewire it by itself through adapted programming tasks. Chameleon chip consists of many functional blocks which are connected parallel to each other with many computational units which can process signals simultaneously. While reconfiguring these chips as per desired, the connections are automatically changed. i.e., the connections between blocks and inside blocks are changed. After loading the software, the old hardware design will be erased and a new hardware design is generated by activating some connections and inactivating some other connections. Hence the system defines the configuration of hardware for loaded software. Chameleon chips can be realized using dye doped nanocomposite materials [25].

(viii) Space Travel : The growing population and diminished resources on earth suggest identifying an opportunity for space exploration. Space exploration also helps us to monitor the health of our planet, a source of resources and an outlet for our imagination. Using carbon nanotubes to make the cable needed for the space elevator, a system which could significantly reduce the cost of sending material into orbit. Nanotechnology will create the ability for humans to operate in space more safely. Applications, where nanotechnology will impact space exploration, are propulsion fuels, coatings, structural materials, smart uniforms, electronics and life support environments. These will be more efficient, stronger, self-healing and lighter than what is currently available [37-40].

(ix) Anticipated Immortality: The dream of every human being is to a leave long time with good health. This can be achieved using nanotechnology innovations. There are two ways in which nanotechnology may be able to extend our lives. One is by helping to eradicate life-threatening diseases such as cancer, and the other is by repairing damage to our bodies at the cellular level - a nano version of the fountain of youth. The most exciting possibility exists in the potential for repairing our bodies at the cellular level. Research in this regard is very active at the laboratory level to achieve and realize these dreams in the 21st century itself [25].

Table 3 : Industries and Industry sectors which use and benefit from Nanotechnology

S. No.	Industries	Industry Sectors/Segments	NT Applications
1	Agricultural & Allied Industries	Agricultural products, Forestry & logging, Fishery.	Nanotechnology based optimized nutrient management, Nanosensors, Nanotechnology based genetic transformation, Nanoencapsulation of nutraceuticals, Nanofertilizers
2	Automobiles	Commercial vehicles, Passenger cars, Three & two-wheelers.	Nanomaterials for energy storage, increasing body strength, efficient engine and body parts
3	Aviation	Civil aviation, Military aviation	Light & strong materials for airplane
4	Banking & Insurance	Public Banking Private banking International banking Life insurance General insurance	Increased efficiency of ICT components and devices
5	Cement	Cement Production, Cement transportation	Nanomaterials for increasing strength, controlling hardness
6	Consumer Durables	Consumer electronics (brown goods) Consumer appliances (white goods)	Increased performance efficiency of goods and devices
7	E-Commerce	E-procurement E-marketing E-payment	Increased efficiency of ICT components and devices
8	Education & Training	Education, Training	Increased efficiency of ICT components and devices
9	Engineering & Capital Goods	Transport equipment, Capital goods, other machinery/equipment and light engineering products such as castings, forgings and fasteners.	Nanomaterial based light weight components with enhanced durability. Nanocomposite based battery and solar panels to enhance efficiency.
10	FMCG	Packaged foods, Beverages, Toiletries, Over-the-counter drugs, Other consumables.	Nanomaterial based cosmetics, paints, food packaging, drugs &sports equipment etc.
11	Gems & Jewellery	Gems Jewellery	Nanotechnology based artificial gems and jewellery
12	Healthcare	Hospitals, Medical devices, Clinical trials, Outsourcing, Telemedicine, Medical tourism, Health insurance and Medical equipment	Nanomaterial based building materials, Nanomedicine, Nanotechnology based controlled drug delivery
13	Infrastructure	Transportation, Communication,	Nanomaterial based parts,

		Sewage, Water and electric systems	filters, power storage devices
14	IT & ITES	E-Communication Cloud computing, Mobile applications E-services E-Business	Nanomaterial based electronic and photonic components
15	Manufacturing	Raw materials, Food manufacturing, Textiles	Nanomaterials used for fabrication to improve the strength and performance
16	Media & Environment	Print media, Radio, TV media, Social media, and film,	Nano ink, Nanotechnology based electronic and photonic components
17	Pharmaceuticals	Pharmacy Drug production Clinical practice	Nanomaterial based medicines, Nanomaterial based controlled drug delivery
18	Ports	Ports Terminal management Shipping	Improved mechanical tensile strength
19	Power	Coal Hydro Renewable energy	Improved technology of power generation, Improved performance of turbines, Solar panel with improved efficiency, Wind turbines with increased durability
20	Railways	Goods trains Passenger trains Railways Infrastructure	Nanomaterial based improved performance
21	Real Estate	Residential sector Commercial sector	Nanomaterial based quality and durable construction materials
22	Renewable Energy	Solar Energy Wind Energy Nuclear energy	Improved efficiency Improved strength Improved safety
23	Retail	Convenience Stores, Specialty Stores, Department Stores, Supermarkets, Hypermarkets, Discount Stores, Multichannel Stores.	Quality and efficient products
24	Roads	Roads Bridges	Nanomaterials for durable roads and bridge construction
25	Science & Technology	Research & Development Emerging technologies Bio-technology Space technology Nanotechnology etc.	Research for new smart materials, new smart components, new and improved devices through improved properties
26	Steel	Iron Ore	Parts with improved strength

		Steel Steel products	and increased durability
27	Telecommunications	Telecom equipment (the largest), Telecom services (next largest), Wireless communication.	Components with Improved efficiency, Improved strength, small size.
28	Textiles	Dying, Treads, Weaving machines	Improved colouration, Improved strengths, Stain-free fabrics, Durable Weaving machines, etc.

4.3 Similarities between the ICCT and NT :

Even though both ICCT and NT are emerging as general-purpose technologies, they are not seeming to be competing technologies. Nanotechnology supports industries to do innovations in material and manufacturing processes to improve the performance quality towards optimum systems whereas the ICCT supports industries to do innovations at application and service side of businesses. Thus, both NT and ICCT works like complementary to each other instead of competitive technologies. Thus, both technologies are expanding with time to many industries by showing all the three characteristics of GPT with Pervasiveness, Improvement over time, and Innovation spawning abilities.

1. In both technologies, productivity growth rates are below those attained in the decades immediately preceding the GPT's arrival.
2. Measures of reallocation and invention – the entry and exit of firms to these business market, investment by new firms relative to incumbents, and grants of patents and trademarks – are all higher during both the GPT's.
3. Expansion to various industries rises gradually during each GPT time.
4. Both technologies are supporting each other and hence interrelated and complementary to solve many problems in the organizations and in the society.

4.4 Differences between the Information Communication &Computer Technology and Nanotechnology:

1. Innovation measures are growing much faster for ICCT than for Nanotechnology – patents and trademarks surge much more strongly during the ICCT era, and the price of IT is falling 100 times faster, at least, than did the price of Nanotechnology.
2. ICCT is spreading more slowly than did nanotechnology, due to the fact that ICCT is an application type technology rather than Nanotechnology which is a manufacturing technology.
3. The productivity slowdown is stronger in the Nanotechnology era than the ICCT era.
4. Nanotechnology supports various products preparation and quality improvement whereas ICCT improves many applications in various industrial sectors.
5. Nanotechnology has anticipated hidden environmental problems and challenges which is not a case in ICCT.

The differences seem to be quite important. But overall the evidence clearly supports the view that technological progress is uneven, that it does entail the episodic arrival of GPTs, and that these GPTs bring on turbulence and lower growth early on and higher growth and prosperity later.

4.5 Measuring the three characteristics of ICCT as GPT :

(1) Pervasiveness of the GPT : The first characteristic is the technology's pervasiveness. The spread of ICCT in various industry segment is immense and the details are given in table 2.

(2) Improvement :As per this characteristics, the ICCT should get better over time and, hence, should keep lowering the costs of its users. ICCT is playing this role more effectively. The technology through its digital model lowered the cost of various processes and their applications to a minimum level due to the strategy of

attaining the cost leadership by various competitors in different industries. The continuous improvement in both minimizing the size and enhancing the speed of ICCT devices, the customers and hence the society is continuously getting benefits.

(3) Innovation spawning: The ICCT as GPT supports to invent and produce new products or processes. ICCT based innovative new products and processes in high speed computing, electronic communication, business analytics, virtual reality, artificial intelligence, 3D printing, digital marketing, cloud computing, Internet of things technologies are becoming more popular and hence ICCT is growing beyond general purpose technology and marching towards so-called universal technology.

4.6 Measuring the three characteristics of NT as GPT :

(1) Pervasiveness of the GPT : The first characteristic is the technology's pervasiveness. Nanotechnology finds its applications in almost every industrial sector as shown in table 3. It has spread its roots in solving both fundamental problems of human beings and offering luxurious facilities in every part and parcel of human life.

(2) Improvement : The GPT should get better over time and, hence, should keep lowering the costs of its users. This is happening nanotechnological solutions. The improvements in material properties and hence the overall performance of devices in almost all industrial sectors support this property of nanotechnology.

(3) Innovation spawning : The nanotechnology as GPT supports to invent and produce new products or processes. In agriculture, it supports to develop new sensors, a new way of controlling genetic transformation, optimization of nutrient management, nanoencapsulation of nutraceuticals, nano-fertilizers etc. It also helps to produce potable water from seawater. It supports to fabricate highly efficient long-life batteries for electric vehicles and allows to fabricate high efficiency solar panels and strong and durable windmills. It also helps to develop an innovative process of controlled drug delivery. Finally, it also supports the most anticipated technology of lifespan expansion of human beings so that is predicted as the ideal technology and technology of the 21st century.

5. CONTRIBUTION OF GPT'S TOWARDS DEVELOPING SUSTAINABLE SOCIETY :

The symptoms of a GPT proposed by different authors with the three characteristics – its pervasiveness, its rate of improvement, and its innovation-spawning tendency are clearly observed in both the technologies ICCT and NT. Apart from these, additional symptoms as listed below are also observed in the case of these two technologies :

1. Productivity slows down initially – The new technology may not be user-friendly at first, and output may fall for a while as the economy adjusts.
2. The skill premium rises with time – If the GPT is not user-friendly at first, skilled people will be in greater demand when the new technology arrives, and their earnings should rise compared to those of the unskilled. This is true in both cases.
3. Entry, exit, and mergers should rise – This feature is also observed in the case of both technologies as the alternative modes for the reallocation of assets.
4. Stock prices should initially fall – This also applicable in case of both technologies. The speed of such fall depends on the way that the market learns of the GPT's arrival.
5. Young and small firms should do better – The ideas and products associated with both technologies are often be brought to market by new firms. The market share and market value of young firms should, therefore, rise relative to old firms.
6. Interest rates and the trade deficit – The sudden increase in the output due to these technologies cause a rise in interest rates or to worsen the trade balance.
7. Improvements in the living standard of people in the society–The contribution of these two GPT's is expected to raise the living standard of people in the society due to their abilities to solve problems related to both fundamental and luxurious facilities for happy life leading.

6. FUTURE OF ICCT & NT :

Both ICCT and NT as general purpose technologies are further expanding their roots to many other industries and becoming so-called Universal Technologies. Universal technology is a technology more than general purpose technology where apart from (1) Pervasiveness, (2) Improvement, and (3) Innovation spawning characteristics, additional characteristics like (4) Universal applicability, and (5) Ideal solutions to problems. The advents of both technologies ICCT and Nanotechnology are presently expanding together in many areas including three very important futuristic technologies which are virtual reality, artificial intelligence, and human life expansion.

6.1 Virtual Reality :

Virtual reality is an artificial environment that is created with the help of computer-based software and presented to the user in such a way that the user suspends belief and accepts it as a real environment. On a computer, virtual reality is primarily experienced through two of the five senses: sight and sound. Currently, the virtual reality is mainly developed and used in simulated training and education as well as the simulated game environment. But it may further find its applications in many other areas including business as augmented reality and may enter the group of general purpose technology.

6.2 Artificial Intelligence :

Artificial intelligence (AI) is a branch of computer science which focus on the creation of intelligent machines that makes decisions like human beings. The main functions of artificial intelligence machines are to recognize the environment such as speech recognition, Learning, Planning, Problem-solving, and hence decision making.

Artificial intelligence machine mimics cognitive functions of human beings associated with other human minds, such as learning & memorizing and decision making for problem solving.

The evidence of computer automated artificial intelligence systems for perception, learning, understanding, and reasoning are already used in the society which includes :

- GPS systems which simplify the complexity of millions of routes to find the best suitable one based on the user's preference.
- Smart phones understand human speech and mobile applications like Siri, Cortana, and Google Now are getting better at understanding user intentions through improved AI techniques.
- Cars from Google and Tesla can drive themselves using currently available AI systems, autopilot systems based on AI technology direct airplanes around the world, and robotic surgeons are operating more exactly and high speed than their human counterparts.

It is predicted that AI enabled super-smart computer devices may allow the blind to see, the deaf to hear, and the disabled and the elderly to walk, run, and even dance. It is also predicted that artificial intelligence is the pivotal step in addressing the grand challenges of humanity and our brains may be able to connect directly with the cloud via nanobots by the year 2030. On the negative side, the uncontrolled and unregulated advents in AI could be a threat to humanity and may have disastrous effects leading to the end of the world.

The integrated version of ICCT and NT applications may support high level advanced and personalized healthcare, virtual reality, and artificial intelligence making human life more comfort and connecting dream and real life of human being on the earth in particular and in the entire universe in general.

6.3 Lifespan Expansion :

Nanotechnology supported Life extension science, also known as anti-aging medicine, indefinite life extension, experimental gerontology, and biomedical gerontology, is the study of slowing down or reversing the processes of aging to extend both the maximum and average lifespan.

7. CONCLUSION :

Technological invention is uneven and emerges in bursts; contributes substantially to the society and changes the lifestyle, culture, and tradition and even thinking of people in the society. Information Communication and Computation

Technology and Nanotechnology are, to most observers, the two most important GPTs to date, according to the three criteria that Bresnahan and Trajtenberg proposed. These two technologies emerging as independent, integrated and complementary technologies with two additional characteristics proposed in this paper that is (1) Universal applicability, and (2) Ideal solutions to problems. Thus, these two technologies are emerging as universal technologies of the 21st century. In this paper, we have analyzed how these two GPTs are spreading to many areas of society and changing the lifestyle of human beings. Having discussed in detail these two GPTs we believe that the technological changes and their effects are spilling over the world. The ICCT and NT innovations differ in some important ways but have made and going to make a further impact on many areas of the society. ICCT is more broadly adopted, whereas NT seems to be technologically more revolutionary and yet to be commercialized so that these two technologies together lead to complete revolution of civilization in this world by solving both fundamental and advanced challenges for human prosperity. The productivity slowdown is stronger in the NT era, but the ongoing spread of NT and its continuing proposed precipitous price decline are reasons for optimism about growth in the coming decades relative to what happened at the end of the 20th century following the spread of ICCT. But it is the similarities between the two epochs that are the most instructive and that will guide our expectations about how the next universal technologies will affect the economy of the world when it comes along [1]. Based on the analysis in this paper, it is also concluded that both the technologies ICCT and NT are potentially contributing towards creating a techno-society and based on further progress and spread of such technologies to every dimension of human life to reach the ultimate level of civilization in or around this earth.

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