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Industry 4.0 and its associated technologies

Krishnan Umachandran[1*]
[1]Organization Development, Nelcast Ltd, India, umachandran_k@hotmail.com

*Corresponding author

Abstract: Rapid implementation of Information and Communication Technology in manufacturing enables the industrial processes to evolve as smart for mass customization, making it something unique and spectacular with the ways of adapting to work facilitated with better communication approaches, and novel classifications in manufacturing are changing the terminology of the Industrial Upheaval. The key impact factor offers a cutting edge to compete with the application of the IoT. Thus facilitating functional requirements to unravel towards the encounters erupting from the technological disruption. The enhancing parameter in novel manufacturing uses digital format information, which supports the content interstellar by considering the people's needs on the dependable data and the progress in the information and communication infrastructure. The potential of people being linked with mobile devices to admittance knowledge sources, bourgeoned by emergent technology, influences the Industry 4.0 to unceasing growth in the IoT, Cloud computing, autonomous vehicles, Big Data, Augmented/Virtual Reality, 3-D printing, energy storage, nanotechnology, robotics, Artificial intelligence, materials science, biotechnology, and quantum computing. Smart Manufacturing is an inclusive strategy, which authorizes the production and generation Ecology to catapult the demand-supply equations on a physical goods/service perspective. This inclusive growth trajectory positions the future of industries to evolve towards industry 4.0. This necessitates the importance of skills and quality as the important parameter for providing cutting-edge deliverables to industries. While preparing themselves for employability in the future, potential and prospective students need to pick and equip themselves with industry 4.0 competent skills for a better opportunity.

Keywords: Digital Economy, Industrialization, Industry 4.0, Manufacturing, Technologies

1. Introduction

The modern digital economy changes the economy's technological base A focused digital strategy to cover, control, and democratize the access and use of data facilitated with infrastructure like cloud computing and ensured with security will facilitate the digital economy and social developments (Sundeep et al., 2020). Affordability in digital technologies ensures that all commercial activities, wherever located and in whatever size, fully benefit from digital innovation. The vision for industry 4.0 is a cyber-physical manufacturing or production system that facilitates or provides intelligent services through digital representation and supports

flexibility through interoperable interfaces connected through networking of production and manufacturing setups. The smartly implanted machines, gadgets, devices, and equipment will commence exerting together impeccably, using the Internet of Things (IoT), while the monitoring and centralized control will decentralize the intelligence of Machine - Machine (M2M) communication on the shop floor.

This automation of the manufacturing facility integrates all the core functions, from the material supply chain, production, and warehousing to the point of sale or commercialization of the manufactured product or service. This seamless integration and prominence throughout business processes are stringed with the emerging technologies that push or pull the organization towards amplified operational efficiency, customer-responsive production services, and accelerated product or service level performance. These smart machines, gadgets, devices, and equipment will optimize manufacturing, While the construction would become more complex as it involves the whole manufacturing environment, which interacts across organizational boundaries. The inclusiveness of dynamic data and completes the digital production establishes projection on a model and replication preceding an investment, right from sourcing the resources (BIS, 2018).

2. Revolution in industries

The revolution in industries is based on various archaeological and anthropological evidence, starting from the potter wheel was the first discovery which eased their effort. During the period 1700-1800, the steam engine's invention paved the way for the inventions of simple machines, facilitating to accommodate the work of the employable resources, who then were more of physical workers or artisans. That was the first revolution in industries. Then the subsequent period 1800-1900, was when the material “steel” and electricity were discovered. This period of the second revolution in industries revealed mass production and mass transportation. Later in the 1950's the electronic components were produced, replacing the electrical components, ultimately progressing for the third revolution in industries with the invention of computers. This period went on to automate many data-based jobs such as automation of clerical activities, scrutiny of data, and trust-building on the accounting and auditing practices. In the industrial scenario, the numerical machines are converted into computer numerically controlled machines, resulting in better controls on the machining process's efficiencies and effectiveness. In 1983, after Tim Berners Lee invented the internet, the industrial landscape changed to accept and heed to implement all automation controls to virtual connectivity accessible, anytime from anywhere. This period of the internet that facilitated the revolution in industries is known as industry 4.0. The machines thus evolved and became a Cyber-Physical System (CPS), transforming the operational process flow into an intelligent environment, as per Figure 1 on industry 4.0 technologies. Therefore industry 4.0 machine, device, gadget, or equipment has a CPS, Artificial Intelligence (AI), Machine and Deep Learning (ML-DL), Predictive Data Modelling (PDM), and Digital Twin (DT) (Umachandran et al., 2019). The key drivers for industry 4.0 is a blend of swiftly increasing technological progress, involving Internet of Things (IoT), Internet of Services (IoS), Cyber-physical systems (CPS) devices, and big data, which are predictably leading to an archetypical swing in industrial manufacturing or production, thus an innovative technology push that aids substantial path forward or leverage for the industry (Koleva, 2018).

3. Technology driver

Digital Twin is a comprehensive digital trail or machine’s footprint, permitting to distinguish the operational or maintenance issues earlier, envisage consequences more precisely delivering superior quality, and reduce all costs, by its virtualization allowing visibility of operations and its interconnected system representation of product and process. This digital depiction of produce, paraphernalia, or process is a blend of data, information, and intelligence, demonstrating the machine's edifice and behavior or device or equipment as a physical system and its dynamics interfacing to understand it as a complete gamut (BIS, 2018). Industry 4.0 will transform the manufacturing process through technological developments such as making it into a digital format and automated, enhanced actualization through robotics, IoT, new materials, artificial intelligence, and nano or biotechnology. Thus, leveraging the developed countries again to evolve as the key foundation for prosperity creation through employment opportunities (Vasin et al., 2018). Online tutoring is expected to

modify the industrial learning, with the amplified need for highly skilled workforces, thus presenting challenges for teachers and learners in educational settings, shifting the students to new jobs, delinking the superior rights of their latent knowledge, initiating active democratic processes and systems in the entrepreneurial society.

The integration of systems and implementation processes ability lies in educating the new generation, developing new technologies, and preparing for the current and future industrial development challenges (Rosine, Jen & Laseinde, 2019). The future jobs will have a higher percentage of it, giving the status of reputation to the cognitive skills and system aids over physical capabilities as core job skill sets. The learning augmentation enthuses the knowledge rationality between students and abridges the teachers' assessment load by aligning to the learning objectives. The online accomplishment verifies the students' tasks, with rules such as time frame, calendar plan, and intended learning content compliance. The final output of evaluation is unbiased for successful implementation and acceptance (Umachandran, 2018). Education technology will enable sustainable economic development, facilitate the re-skilling of workers and lifelong learning to bridge the gap between skills and jobs, and, ultimately, increase economic productivity (Sundeep et al., 2020).

With the priming of innovation in technological upgrades, digitalization will generate creative models in carrying out the business, operations, functionalities, and automated programs that will intensify the returns to the topline and grow upon the delivery competence and commercial efficiencies. Thus, the applications of innovative possibilities through web services or online facilitation and advanced digital platform applications would make the economic system be more viable and accessed by individuals, corporates, and the government authorities with complete transparency and disclosure through innovative digital applications in their practice for all the aspects of business and operational processes, output such as product or services, functional systems, and delivery services, which controls their executive process being fulfilled to become complete, with evidently well-defined business responsibilities and data (Vasin et al., 2018). Industry 4.0 is a revolution that has the strength to essentially modify the economy, intensively aggregated in digitization, and substitute older analog versions of automation. It is also considered to develop economies of scale and availability on-demand with indebted capital cost, reduced energy costs, and affordable employee costs (Koleva, 2018).

4. Resources preparation

Quality in industry 4.0 education is one of the sustainable development goals, especially in emerging markets, where access to education is granted with technology's role in achieving faster progress on the education side, both for basic education and for industry-specific skills (Sundeep et al., 2020). Industry 4.0 would use the best of the programmed resources in source planning by customizing versatile programs and prognostic algorithms to perform more qualitative scrutiny, allowing the manufacturing, production, or service process to become more optimum and accomplished minimum and virtual controls or maintenance. It will overcome the manufacturing or production derails such as technological obsolescence, process deficiencies, and many more by minimizing such parameters in manufacturing organizations to slack ineffective utilization of the deployed resources (Koleva, 2018). Entree to quality enhanced ICT infrastructure affects the GDP growth and the likelihood of developing digital amenities. Thus, demanding wide-area networked internet access in all industrial establishments, households, and educational institutions, domestic digital platforms have to be upgraded with the deployment of 5G networks to enable the Digital Economic rapid implementation (Vasin et al., 2018).

Technological Infrastructure needs to undergo pivotal change with an increase in digitalization, and the rise of online retail also changes the demand for urban real estate. The decline of physical shopping will curb demand for retail space in town centers, while demand for warehouse space and data centers will increase (Sundeep et al., 2020). The rewards that the developing economies have so far reaped through their tall progress rates are deploying low-priced labor employment, which would no longer be a systemic factor that

provides commercial development. Hence competing for aspiring countries that aim to evolve should reach the common infrastructure plank by quickly revamping their industrial policies that can endorse inclusive and innovative economic advancements (Vasin et al., 2018). People are still vital and creative unique resources towards pioneering product generation.

The life essence, ingenuity, and entrepreneurial development plays a very crucial part and urges for equipment's or gadgets or devices to replace the human element in executing monotonous and tiresome manufacturing or production activities, interacting among the various business process units to endure a fundamental modification as of the progressively fading people deployment with respect to work automation (Koleva, 2018). Anticipating the forthcoming significance of automated technology applications for the people and work areas, the amazing stride of revolution is integrating ICT demand with increased computing and storage, data transmission speed, and network connectivity, while costs have fallen rapidly. There is a sharp increase in the demand for more skilled labor, requiring retraining of the existing people to prosper out of the emerging technologies. This up-gradation in technology supports the workforce's education and training in the pre-entry stage and continuous learning. Technology-enabled learning uses computing gadgets as an essential fragment of the educational process; and is swiftly accelerating as the applications are available as online content, further customized to the learning groups. Web-based ICT possibly allows access and always uses the learning content and from anywhere (Karoly, Panis & Panis, 2004).

5. Society changes

Industry 4.0 results from the organizational efforts absorbed on applying emerging technologies and leverages decent prospects to become free off from the ever-rising employee costs (Koleva., 2018). Developing a competitive marketplace to allow the private sector to develop has been on many governments' radar to boost its economy. In this race, many countries have established exceptional technology and employee skills to secure cutting-edge excellence and enhance their competitive advantages (Sundeep et al., 2020). The social acceptance and exhaustive expansion of the digital economy offer sufficient solutions to difficulties in the arena of information administration. Learned knowledge gained through experience is the significant resource that shall foster innovation, creativity, competence, and cognitive effort, which offer the competitive returns for excelling in the global market. Thus, the conversion from brick and mortar to a digital economy necessitates unconditionally newer methods not only in the industries but in the development of individual competence for the evolving economy in digital mode, which includes computer education, ICT training, Research-innovation, and finally the management of knowledgeable workforce which are advanced human resources in their skills and talents (Vasin et al., 2018). To leverage technologies, enterprises test or create small-scale solutions for Industry 4.0, while the capital-intensive industries such as the automotive industry that require high-skilled laborers are the ones that are pioneering the adoption (Bhat, 2020).

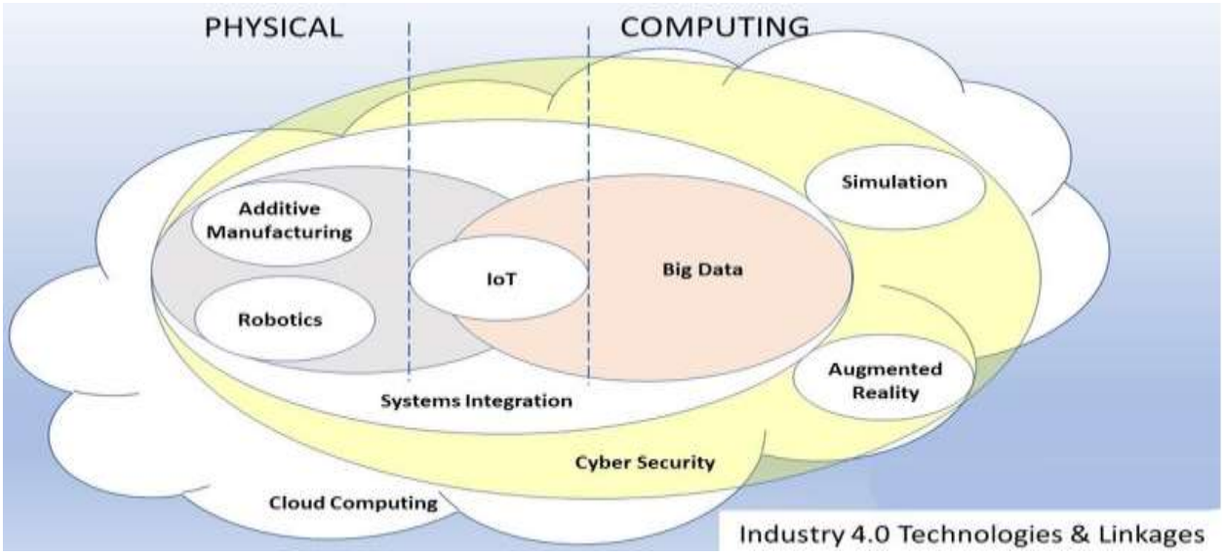

Figure 1: Industry 4.0 Technologies & Linkages. (Adopted from Umachandran, 2020)

6. Industry 4.0 technologies

This is an embedded system known as cyber-physical systems (CPS), connecting computers and networking infrastructure to control physical processes through various technologies. Industry 4.0's capability to act as an economic game-changer will open up an innumerable of prospects for organizations to refurbishment or produce completely novel offerings and business mockups, over scientific revolution that can centralize to a supply-side phenomenon, through enduring benefits ineffectiveness, throughput, likely to increase comprehensive revenue levels and advance the quality of life for people globally. Industry 4.0 is the succeeding step in the extended course of expansion, an upheaval founded on the application of cyber-physical structures. The applied skillsets for industry 4.0 have Machining Skills which for its effective use requires various interventions known as Technology Skills. Machining Skills are to be developed in line with the Cyber-physical systems architecture requirements such as Connection, Conversion, Cyber, Cognition, and Configuration. The core component of AI is in ML to communicate with human beings and to gather countless real-time information performed with one another; thus, the learned inputs ought to cover the substances such as Probability, Statistics, Optimization, Data Visualization, Computational methods, Data Science, Database Systems (SQL and NoSQL), Operating Systems and finally data acquisition for coordinating with the cyber-physical levels of architecture. Technology Skills should be cultivated quickly among the employees or users so that they possess predictable advanced skills in ICT, data analytics, and others. The technology skills acronym as "2S 2C 2A IBR" are to be groomed on Simulation, Systems Integration, Cloud Technology, Cyber Security, Additive Manufacturing, Augmented Reality, IoT, Big Data, and Robotics (Umachandran et al., 2019).

Simulation - It is an imitation or pretentious scenario for automation. The basket of tools in a simulation is right from the drafting and design stage. It includes the product, process, services, safety, usability, repairs & maintenance, accidents, and hazards. Simulation is a powerful and widely recognized technique for approaching the manufacturing industry's current challenges; it presents a huge potential for product and manufacturing process development and improvement. To analyze several scenarios, a large amount of modeling time is usually required, and although an improved scenario can be found, an optimum solution cannot be guaranteed. It is not an optimization tool by itself, but by combining simulation and optimization suitably cases with - where, what-if scenarios can become a time-consuming and tedious task due to the increasing number of possible solutions (Zúñiga, Moris & Syberfeldt, 2017).

Systems integration - In these machines, there are sensors connected and spike signals or data. The hardware and software need to be integrated. Vertical Integration is intra plant oriented to connect all the

processes of the enterprise. The Horizontal integration is interplant-oriented, linking all the other enterprises that provide service to the parent organization. For example, in SCM, the parent enterprise is connected to all its suppliers, sub-contractors, sub assemblers, and vendors. In Marketing, it includes all the connectivity between all the distributors and stocks with whom the parent organization is connected. In logistics, it connects the network of all point of sales (POS), who directly contact the customers. Vertical integration networks the smart manufacturing production systems, utilities, and services with robust requirements, oriented to adapt operational flows. Horizontal integration develops an innovative group of an international network comprising aggregation and integration of all stakeholders. "Through-engineering" is possibly existing in the complete value chain, attracting the whole production process and the product in the entirety of its product life cycle. However, the acceleration is through the exponential use of technologies such as sensor technology's connection (Koleva, 2018).

Cloud computing - Cloud is a pathway to connect the computing services such as servers, storage, Database, Networks, software's, and analytics. They are three forms: Cloud, Fog, and Edge, involving widespread edge data management networked through the sensor to the cloud for the omnipresence of data availability, access, and use. Cloud is a collective pool of embedded computing systems and complex services that can be quickly arranged with trifling administerial effort through the internet, depend on to attain consistency and marketable volumes, for a civic value. Edge computing acquires, compresses, and aggregates huge volumes of data nearer to its source of generation using dispersed devices – and then converts that data into plausible intelligence (BIS., 2018). This provides services such as Software as a Service (SaaS), Platform as a Service (PaaS), Infrastructure as a Service (IaaS). These services are safe, secure, simple, scalable, flexible, affordable, and innovative.

Cybersecurity - Cybersecurity is the shield of networked internet systems, such as hardware, software, and data, from vulnerable cyber-attacks. It encompasses cyber and the physical safety of both applied in an enterprise being safeguarded from unlawful admittance to data centers and other high-tech schemes. The security of data protection designed to uphold the secrecy, veracity, and accessibility of data, is a subset of cybersecurity (BIS, 2018). As more people will use data, it needs to be protected as far as the responsibility to use and accountability to be relied upon. The security aspects would include assigning the Assess Rights to policy governance of the organization or business requirement, Traceback and rectify in case of any problems through Trails, use as a bounce-back without loss of time by using Disaster Recovery System (DRS). Industry 4.0 is a promising paradigm evolved on the emerging Internet of Things (IoT) technologies and CPS, defined to increase the value chain efficiency in manufacturing (Zúñiga et al., 2017).

Additive manufacturing - Like 3D printing, this evolution of novel manufacturing techniques such as Optical fabrication, Photo Solidification, and Fused Deposition. This leads to flexible manufacturing of all other conventional methods of mental formations such as casting, forging, extrusions, and metal joining operations such as welding, riveting, bracing, soldering, and all other types of fabrications. It will use less of the resources and cost affordably for all small manufacturing units to facilitate batch order productions. Additive manufacturing is a comparatively novel manufacturing method through material joining processes as deposition laid one over another as layers to make objects from 3D models, unlike the conventional method where the material gets removed from a blank. Change agents for additive manufacturing focus on reducing manufacturing costs, fast-tracking the returns, and snowballing additive manufacturing profits. Although it permits the production of demandingly intricate parts, the sluggish printing process speed restricts their use for mass manufacture. 3D scanning has aided the duplication of physical items exclusive of molds, which are trying and cost aggravated. The additive manufacturing systems lessen the consumer's issues through faithful interaction being associated with manufacturers and wide opportunity to customize products from the rise data assemblage from the customer. A basic 3D printer permits the customer to produce polymer-based products well within their resource availability of any typical purchaser. It opens wide prospects for the economy and society and enables the manufacture of robust to light-weight products. It consents projects that

were not conceivable with conventional production techniques, even in revolutionizing medicine with biomanufacturing (Thomas, 2013).

Augmented Reality - This technology layers computer-generated augmentations atop any prevailing reality to make it supplementarily expressive and through the facility to relate with it. AR apps are applied in mobile gadgets to merge digital data into the physical ecosphere in a way representative and improves upon one another (BIS, 2018). This is an overlay of digital content and information. It is connected to a transparent glass base, either as a wearable or projected surface. The superimposed, computer-generated images sync with the real world and provide the pathway to be connected for further actions. They link the dynamic inputs to various devices such as drone cameras or night vision cameras they can be used for security or defense operations and in industrial maintenance.

IoT - The Internet of Things is an integrated computing device. The mechanical and digital machine gets connected through IoT by the components such as Sensors attached to Machines or gadgets or Devices, interfacing the users with interoperable data connectivity. Autonomous systems use exponential AI, and Quantum computing, while medical applications during surgeries opt for bio digital integrations at a higher-order level. Radio Frequency Identification (RFID) is a prerequisite of IoT facilitating Real-time Location Systems (RTLS). The location systems can vary from being passive, active, ultra-wideband, Wi-Fi, and Infrared. Passive RFIDs do not inform where the tagged item is available, whereas an active RFID is like a Bluetooth device that identifies the tracked item's location. Ultra-wideband RTLS uses radio signals, identifies the item when it comes into the signal covered area. Wi-Fi RTLS requires Time of Flight (TOF) and Time of Arrival (TOA) measurements to pin up the item, wherein the location Wi-Fi connectivity is available. Infrared RTLS cannot pass through walls which is its major limitation.

Big Data - This analytics is the progression of assembling, forming, and investigating huge data sets to realize forms of correlation and supplementary beneficial evidence, appreciate the evidence confined in the data, and recognize that which is of utmost vital to the current and future business decisions (BIS, 2018). It is a voluminous variety of data that needs to be analyzed faster for obtaining enriched data. Big data goes through warehousing, computing, engineering, and finally, data mining for facilitating decision-making outputs. Applications are varied but successful results in a digitalized economy have already been experienced in Customer Relationship Management (CRM). Big data analytics is leveraged for long-term demand forecasts, transportation fleet capacity optimization, and planning and management; to identify carriers that can accommodate additional freight/passengers (Bhat, 2020).

Robotics - It is interdisciplinary applied information engineering on computer science using electro mechatronics and other specializations. The plan, structure, action, and use and systems to compute and control, including sensory feedback and data dispensation, ensembled for development to support applications that substitute human actions. Robots are completed to be similar to humans in their presence and replicate activities such as walking, lifting, speech, and cognition. With aviation, support robots carry out astonishing fleets through unmanned aerial vehicles (UAV). These drones resemble an aircraft but unmanned aircraft system (UAS); and operate in numerous degrees of freedom: moreover, under control by a human or remotely accessed or unconventionally by dedicated computing machines (BIS, 2018). These machines relate to multiple cameras or embedded vision systems for deterministic positioning and actuation. Robots find themselves applied in all areas, including such as terrible sources of contamination (SOC) and hard to access (HTA). They offer greater repeatability, reliance, and quality adherence.

7. Technology penetration across industries

The period 2010-2020 was defined by technology disruption, with technology scantly penetrating many industries. As per fig 2, the technology adoption curve is just at its beginning, and that digital penetration is set to accelerate. Technology firms have dominated digital innovation, but now technology-enabled incumbents are striving to make up for lost ground and wrest back control of their industries' future. They

prioritize investments in crucial aiding technologies like cloud, mobile, big data, and social networking, and in the higher end evolving ones like AI, blockchain, and many more. Unlike in developed countries, where the internet journey emerged with computers, the developing markets use their phones extensively connecting to the internet. Mobile apps are available for everything, instant communication, shopping through e-commerce platforms, payment transactions are online, aggregated travel service providers are available, food delivery chains, health, wellness, and exercise fitness through telepresence apps.

Together with technology firms, the forward-thinking incumbent organizations would drive the future of digital transformation and accelerate the pace of disruption. The momentum will put technology laggards and organizations that fail to adapt at significant risk of losing market share, as their market will fuel innovation and provide significant growth opportunities for the evolving businesses (Sundeep et al., 2020). Industry 4.0 machines, devices, or equipment are transforming industrial establishments by digitizing manufacture, built on established datasets of design ideologies that associate people, processes, practices, systems, locations, and machines that need to become interoperable, see-through, machine-specific support, and decentralized conclusions. It is a real-world resource for flawlessly mixing machinery, automation, robotics, data management through the internet in industrial establishments where assured quality, ensure reliability, planned maintenance, foreseen planning, predictable prognostication, useful innovation, and magical discoveries are possible, with the shortest time to market, effective supply chain, throughout the production environment. Industry 4.0 has significant interests in the industrial world and by extensions covers various sectors, with big data analyzes the real-time production statistics and adaptation to processes is through digital information seeking and annexation; enabled data flow for wide usage, flexibly productive that will intensely reduce the cost of manufacture while increasing to demand-driven volumes, nimbleness and success (Siemens Financial Services, 2019).

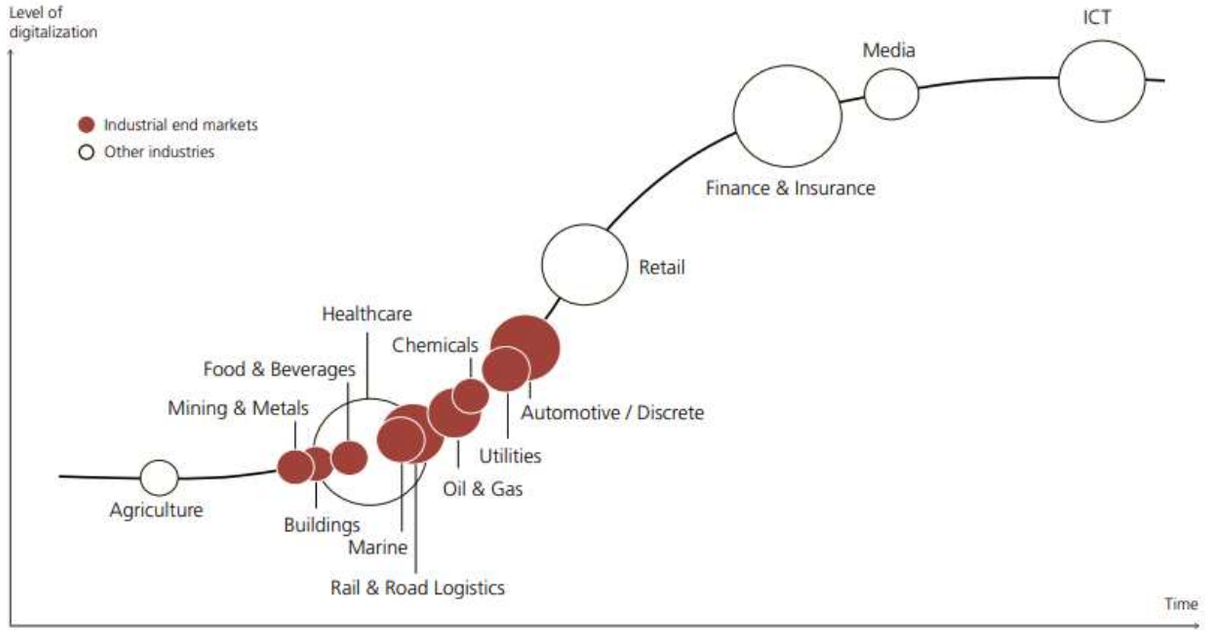

Figure 2: Technology Proliferation. (Adopted from Sundeep et al., 2020), Future of the tech economy

8. Preparation for change

As early as in the year 2000, the online e-learning distance instruction came into being, later got ascended by a cumulative online occurrence, leading to the open education prospects established to form Massive open online course (MOOC), available over the intervention of internet and is made available to many interested learners online, mostly open access with unlimited participation via the world wide web (Rosine et al., 2019). The future jobs will have a higher percentage of it, giving the status of repute to the cognitive skills and system aids over physical capabilities as core job skill sets. Prioritization is seldom a unidimensional dialog; it should

be based on the level of effort required or the value attached, or the competitiveness required. Consequently, grooming aids mix the recent intuitions into the imminent liberal with a preconditional alignment with the students right from the start of the learning activity, with the requirement as a sparking interest. As per the AMSTER Grooming template, the competent skills are Academic excellence, Machining Skills, Self-managing Skills, Technology Skills, Engagement Role Skills, and Radiant Skills. Of this basket of Skills, the cluster of assignments can be classified as Cerebral Skills, Behavioral Fine-tunes, and Applied skill sets. Technology-enhanced and improvised education can congruently be at the expense of students' social education scenarios, while algorithms can reinforce the limits (Umachandran, 2020). Digital technology will make education delivery more productive and efficient. The deployment of educational technology will create a disruptive trend in the global education market; thus, learning will migrate from a capital-talent-intensive (brick-mortar business) into one fit for the digital era, making it easier for less capital-intensive to deliver more personalized education that will enable reskilling (Sundeep et al., 2020).

9. Conclusion

Manufacturing, agriculture, and some service jobs were once physically demanding, but a technology that allows people to hold multiple jobs and work longer from anywhere and in real-time spurred changes in compensation and labor market structures. Thus, working remotely will enable people to live in affordable and convenient housing while avoiding the time, the expense of commuting, and resulting in expenditure. Pessimistically there lingers a doubt that these working arrangements will continue to become more flexible, without some sort of mechanism to broadly share productivity gains, thus sealing the opportunity to grow for the common masses who will remain living and working only a few hours a week, based on their existing skill sets. The industry 4.0 technological revolution will unwind the per capita incomes in emerging markets and are more at risk in the years ahead. Emerging markets may therefore need to undertake more change than developed economies. Thus, the employment opportunity in niche segments would become creamier than now, demanding the students to learn from anywhere, devote attention and time, acquire new skills, and seek employment opportunities using the information technology revolution. The ultimate alignment of these combinations in these CPS machines with embedded or networked sensors, software, and analyses will visualize, regulate, and strategize for enhanced socio-commercial consequences affiliated to the timelines and goals envisaged as achievable by industry 4.0.

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ORCID

Umachandran Krishnan https://orcid.org/0000-0003-4934-4368

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