Practical Lessons for Engineers to adapt towards Industry 4.0 in Indian Engineering Industries

Sony, Michael and Aithal, Sreeramana

College of Engineering Technology, Srinivas University, Mangalore 575 001, India., College of Management Commerce, Srinivas University, Mangalore, India,

5 August 2020

Practical Lessons for Engineers to adapt towards Industry 4.0 in Indian Engineering Industries

Michael Sony[1] and P. S. Aithal[2]
[1]Post-doctoral researcher, College of Engineering & Technology, Srinivas University, Mangalore 575 001, India.
Email: emailofsony@gmail.com
[2]Vice Chancellor, Srinivas University, Mangalore, India,
E-Mail: psaithal@gmail.com
August 2020

ABSTRACT

Industry 4.0 is the current buzzword in the modern organization. It promises to revolutionize the Industry with automation and computing technologies. Indian Engineering Industry is the largest segment among the Indian Industries having a huge export potential. Industry 4.0 is making inroads into this high potential Industry in a gradual manner. There are very few studies as to how should engineers adapt with the skills and ability requirements of knowledge society created due to the application of Industry 4.0. The main aim of this paper is to critically analyze the previous studies so that engineers can adapt to Industry 4.0. This study finds six dimensions engineers must adapt while working in Industry 4.0 environment. Though there have been numerous literature reviews on Industry 4.0, however this is the first study carried out on engineer adaptability for Industry 4.0 in the contextual domain of Indian Engineering Industries.

Keywords: Industry 4.0, Cyber-Physical-Systems, Knowledge Society, Engineer Adaptability, Literature review

1. INTRODUCTION :

Industry 4.0 through the technologies such as "Internet of Things (IoT)", "cloud computing" and "cyber-physical systems (CPS)" has changed the manner business in conducted in organizations. Industry 4.0 is associated with a paradigm shift and is termed as the 4th industrial revolution. The physical and the cyber world is interconnected using technologies such as "semantic machine to machine communication", IoT, CPS, "Embedded Systems", etc. [1] [2]. Thus, it represents conglomeration of technologically advanced "manufacturing systems" featuring a technological concept called "smart factories". It further integrates the physical systems such as production or manufacturing systems with network connectivity through IoT and CPS to achieve the objective of Industry 4.0 [3]. Typically, Industry 4.0 is implemented in the organization by three levels of integration i.e. "(i) vertical, (ii) horizontal and (iii) end-to-end integration". The modern factory is thus becoming more complex and intelligent due to "big data analytics", "machine learning" and "cloud computing" with the advent of Industry 4.0 [4]. Besides, technology enablers such as IoT, CPS, and Industrial internet makes the modern-day workplace a complex phenomenon [5]. In this highly automated and integrated computing environment, the role of engineers will be challenging. It is because all the jobs containing repetitive and simple activities will be done by the intelligent and self- regulating CPS. Those higher-order jobs which are left for the engineers will require higher process integration, cross-functional perspectives, decrease in categorized levels, less demand for centralized management capabilities. In a nutshell, it can be described as the existing jobs will become complex requiring a large repertoire of skill set [6–8]. The "United Nations Industrial Development Organization" (UNIDO) posits that among the 10 global front runners in Industry 4.0, India is the only middle-income country which is rapidly transforming its production units using Advanced Digital Production (ADP)(UNIDO, 2020). The growth of the Indian engineering sector has been remarkable, and this is evidenced by increased investment. To be a global superpower Government of India has selected Engineering export promotion council (EEPC). The Indian Engineering Industries represent the largest segment in the Indian Industry. It is also India's largest foreign exchange earner, as it contributes to 25% to Indian total exports in goods. It additionally, has 30% weight in India's Index of Industrial Production [9]. The engineering industries being labor & capital-intensive, the application of Industry 4.0 will lead to competitive advantage in both internal and external markets. Engineers being the pivotal element in the application of Indian 4.0 in Indian Engineering Industries, it is pertinent, therefore, we ask the research question *What are the practical lessons for engineers to adapt to Industry 4.0 in Indian Engineering Industries?*

2.0 RELATED WORKS :

The introduction of manufacturing automation and commercial robots will reduce employment opportunities for low skilled workers. Artificial intelligence, machine learning and software automation can impact human employability and work for organization. The jobs at present done by graduates may be done by machines with powerful software algorithms [10]. The new age technological revolution will eradicate routine jobs. Furthermore, the highly skilled jobs will require skills such as pattern recognition, mentally loaded non-routine tasks, creativity and application of cross functional skill [8, 11, 12]. The risk due to automation and computerisation on jobs such as telemarketers are 99% compared to 0.28% for the recreational therapist. Most of the routine jobs would be eliminated and the remaining jobs will become more complex ,comprehensive and highly skilled [7]. A leading consulting group, however predicted that hundred thousand odd jobs would be created, and this would be in the field of mechanical and construction-related fields in the next 10 years. Their rationale is CPS would require engineers with a significant amount of technical expertise [13]. At operational level, most of the jobs which are at lower skill level will be replaced by CPS. The emerging technologies will lead to better devolution in decision making and planning. Consequently, demanding elevated process integration and cross-functional perceptions. Such a trend will result in a breakdown of tiered levels in an organization, thus, there will be minimal demand on the central management abilities [14]. The jobs such as quality assurance and maintenance would undergo a sea change due to automation. The intricacy of these jobs is going to change, due to completely "integrated manufacturing processes", "cross functional challenges", ICT polarised technologies, etc. This will result in a need for engineers with "cross-functional skill capabilities", troubleshooting systems holistically and suggest improvement of system considering the big picture [6, 8, 15]. In a survey among 518 companies on the views on the consequences of Industry 4.0, 51 % respondents expressed less amount of manual jobs, 54% expressed an increase in "planning and control activities", 86% expressed interest in lifelong learning activities, 77% on interdisciplinary learning cooperation and 76% expressed high standards of IT competence. The future workforce will shrink but will not result in worker less factory [8, 16]. In another study on managers, it was found that teamwork, handling social media risk, customer ideas in product development, better work life and partner networks will be important [8]. Industry 4.0 will require engineers with ICT skills and therefore, it will polarise the job market creating demand for engineers with ICT and middle and lower educated engineers or workers such as diploma holders will have a difficult time to adjust [17]. In the modern day organization, the employee performance is a single global indicator which will reflect the professional success to meet the global objectives of the organization [18]. A single indicator of employee performance is much like efficiency where the result was on the output. Researchers tried to demystify the black box concept of employee performance by studying the various mechanisms of employee performance. The previous researchers have conceptualized employee or engineer adaptability as a multifaceted phenomenon. The multidimensional perspectives were needed as it reflected various behaviors which were necessary to accomplish the requirements or objectives of the organization. Consequently, researchers examined the "task and contextual performance" as a separate concept of adaptability of employees [19]. The environment around the modern-day workplace is changing constantly. These modifications to the nature of demands have an influence on the kind of work, its management, learning practices, empowerment practices, demands etc. [20, 21]. To examine such dynamic nature of work and employee performance at work, the concept of adaptability of employee was brought forth. The first generic model of adaptability of employees was proposed by Pulakos et al.(2000) [22]. He has defined the eight dimensions to which employee has to adapt. These dimensions of adaptability were "handling work stress, handling emergencies or crises, demonstrating physically oriented adaptability, dealing with uncertain or unpredictable situations, learning new tasks, technologies and procedures, demonstrating interpersonal adaptability, demonstrating cultural adaptability and solving problems creatively". Charbonnier-Voirin

& Roussel [18] further refining the concept of adaptability found five dimensions to represent adaptive performance "(1) Creativity, (2) Reactivity in the face of emergency, (3) Interpersonal Adaptability, (4) Training and Learning effort, and (5) Managing work stress". Sony and Mekoth (2014) [23] in the context of power sector found seven dimensions of frontline employee adaptability. The dimensions were "(1) Interpersonal Adaptability, (2) Service offering Adaptability, (3) Political Adaptability, (4) Social aspect of adaptability, (5) Physical Adaptability, (6) Group Adaptability, and (7) Organization aspect of Adaptability". They further developed "FLEADAPT" scale to measure the frontline employee adaptability [24].These studies on employee adaptability transpire that the dimensions of adaptability will be contextual in nature and general models of employee adaptability will not suit situations such as understating the adaptability of Engineers towards Industry 4.0. The dimensions of engineers adaptability will be different, because the practical application of Industry 4.0 will result in the conventional nature of employment, its composition, duties, assignments, interactions etc. to change drastically [8, 20, 25–27]. These changes call for engineers to adapt to different dimensions of adaptability. The engineers may adapt to these elements differently depending on their individual skills & abilities. The engineers may respond to changes in these work circumstances by changing their activities to those work circumstances or any new occurrences. Therefore, it becomes important to investigate the engineer's adaptability dimensions in the context of Industry 4.0.

3. METHODOLOGY :

The present study is focused on exploring the practical lessons for engineers to adapt to Industry 4.0 environment. A review methodology suggested by Tranfield, Denyer, & Smart [28] was followed. The three phases of the methodology used in this study were 1) articles were searched using keywords on Industry 4.0. The keywords suggested by Industry 4.0 by Liao et al [29], were used as a guideposts. The search database was IEEE, Science Direct, Taylor Francis and Emerald. The duration of the search was 2010 to December 2019. The primary purpose of the analysis was to answer the research question

"*How should Engineers adapt towards Industry 4.0 in Indian Engineering Industries*"

and therefore, the results were recorded in a thematic manner. The primary analyses consisted of first order thematic classification of engineer skills and ability requirements for Industry 4.0. The second order thematic classification of the skills and abilities were carried out for merging the first order themes to create a higher order categorisation of skills and abilities.

4. PRACTICAL LESSONS FOR ENGINEERS FOR ADAPTING TO INDUSTRY 4.0 :

4.1 Practical Lesson 1: Engineers should adapt on Interpersonal Level

Engineers should demonstrate the ability to adapt their interpersonal approach to work together with others from their own company or other partner group or companies [18, 23]. The "vertical integration" in Industry 4.0 is the integration of different types of IT systems at various hierarchical levels. The integration network will require engineers from different hierarchal departments to adapt their style of work to work with others. To cite an example, engineer from design, marketing, production, sales department will be in constant touch due to "vertical integration". Compared to traditional systems, in Industry 4.0 due to "vertical integration" of different departments, almost every engineer will have to interact with various others in the department and adapt one's work practices as per the requirements and suggestions of others from other departments. The "vertical integration" will bring in transparency and sharing of information [30], however, there is also a need for cooperation and coordination to carry out one's work. The "vertical integration" will also result in engineers from different department to interact on some common goal or objectives, therefore understanding other viewpoints will be a critical factor for every engineer to adapt to one's Job. The "horizontal integration" in Industry 4.0 will result in strong integration with other participating partners in the supply chain. The different partners/ members in the supply chain are kept together by the strategy and not by proprietary rights. This will result in strong integration with suppliers, retailers in terms of data sharing, capital, human resources. The "end-to-end integration" will also result in value chain being extended to customer service and the direct monitoring by the manufacturer. This will make possible the concept product-to-service integration a reality. The engineers will, therefore, need to deal with customer needs throughout the stage of a product life cycle. In addition, the instant communication due to three forms of integration will result in a new form of digital connectivity. This will result in developing a breeding ground for new "social and political power relations" for despotic governance by anybody who possess the power to control these digital network [31] in organizations or societies, therefore engineers need to possess a new forms of social skills to communicate at interpersonal level to deal with such power structures.

4.2 Practical Lesson 2: Dealing with emergencies and unexpected circumstances

The ability of the engineers to deal with the emergency or an unexpected circumstance will be a significant dimension of engineer adaptability. "Vertical integration" in Industry 4.0 will result in the seamless integration of hierarchical levels with the exchange of data, capital and resources. To cite an example, a risky or dangerous situation in one department e.g. data theft or a cybersecurity issue by virtue of integration the risk will be transferred to all departments and engineers in all departments have to handle the emergency and unexpected situations. A primary challenge for effectively managing such an emergency and unpredictable scenario wherein the is transfer, receiving and assimilation of expertise across all the participants within an organization. Therefore, the engineers must be apt at it for processing the information to solve interdisciplinary problems. Also, from a pragmatic perspective the challenge is complex. This is because engineers need to apply their abilities, strategies and tools which will not only solve the problem at hand but also to facilitate the transmission, receiving, and integration of expertise across vertical integration network within the value chain in the organization. In horizontal integration of Industry 4.0, due to the integration with all partnering organizations [3], any emergency or risk or dangerous situation in any of the partnering organization will result in engineer all along the horizontal chain to take appropriate action to handle the emergency situation. The acquisition of such skills takes time and often is based on intermediary cognitive capacities and skills along with understanding of total value creation process across the participating organizations. In the end-to-end integration, the data of usage along the product life cycle can result in emergencies or unexpected circumstances or risks. E.g. product failure in customers hands due to the "end-to-end integration" the risks or emergencies will have to handle by the engineers in the manufacturing organization. Therefore, the application of Industry 4.0 will require engineers to deal with emergencies and unexpected circumstances.

4.3 Practical Lesson 3: Creative Problem Solving

Problem-solving is one of the most widely sought-after skills by an employer. With the implementation of Industry 4.0, most of the standardised and manual jobs are going to be on the decline and there will be a shift towards higher qualified jobs or knowledge based jobs [8]. Industry 4.0 framework treats knowledge as valuable resource. In simple words we can think of it as something instrumentally useful for Industry 4.0. This is aimed at automation, integration, and performance. It might also be regarded as a set of principles or methods for coping with implementation of Industry 4.0 along with responses of various stake holders towards it. In the Industry 4.0, perspective understanding also establishes a pattern as to how it should be implemented in an organization. This will enable in the successful application of Industry 4.0 [32]. Knowledge will be the most important resource in the era of Industry 4.0 and the requirements of engineers who are essentially "knowledge workers" will be immensely important to solve "complex engineering problems", through "creativity and innovations". Additional point to be taken into account is that in the "higher-order jobs" such as in Industry 4.0 [7], the problems are different or ill-defined . Therefore, based on the context of Industry 4.0 application, the frequency of such problems will diverge. The "vertical integration" of Industry 4.0 will require the engineer to solve problems which are multi-disciplinary in nature due to the vertical integration of many departments within the enterprise. The domain of the problem will not be restricted to one department but rather in more than one department. Such complex and ill-defined problems will require creativity to solve it. With the "horizontal integration" in industry 4.0, the different participating organization are integrated, therefore, most problems will be multi-organizational in nature which will have a multi-objective to be handled for a solution. Additionally, while solving such problems the strategic intention of all the collaborating organization in the supply chain should not be disturbed. The solutions to these problems will have to implemented by more than one organization. The "end-to-end integration" is the integration in different stages of the product life cycle. The large amount of data will have to be collected & analysed in this integration. The creative analysis of the data will create insights, which can create new business opportunities and sustain existing strategies. Therefore, the creative problem-solving ability will be the key to solve such complex problems due to the implementation of Industry 4.0.

4.4 Practical Lesson 4: Continuous Learning, Training and Education

As a consequence of the application of Industry 4.0, there is growing complexity of the jobs and understanding the nature of task an engineer undertakes will periodically undergo a change. The technology requirements of Industry 4.0 will be constantly changing, therefore there will be a need for those workers who will continuously update their learning, training, and education in their own domains as well as related cross disciplines. The domain knowledge of most of the disciplines may be polarised towards the information technology and artificial Intelligence [33], consequently engineers will have to be updated on these skills. The productivity of these engineers will be their own responsibility and hence they will have much autonomy [33]. That brings in the challenge where in engineers will have to learn these skills in their own interest in a fastest possible manner to be competitive. Therefore, the “vertical integration” in Industry 4.0 will require engineers to learn skills from other departments in order to be effective in their jobs. For example, a person in accounts department will now require in-depth operations knowledge to be effective in their jobs. Consequently, engineers will have to continuously learn, train and educate themselves not only in their own domain knowledge but also related cross disciplines [34]. The engineers will have to learn these skills on their own in an autonomous and self-regulating manner to be competitive and to be employable. In addition, the management can facilitate learning in organization by organizing learning mechanisms in terms of technology, division of labour and social interactions between various participating departments within organization to facilitate smooth vertical integration. The “horizontal integration” of Industry 4.0 would result in the integration of technologies of all the partnering organization to come together under a common technological platform. For the success of this philosophy engineers working in different partnering organization will have to keep abreast in terms of learning, training and education about the technologies and practices in other partnering organizations. In the “end-to-end integration” in Industry 4.0, the engineers will have to learn, train and educate themselves in large repertoire of skills to be adaptable in “end-to end integration” in Industry 4.0 [3]. For example, engineer in manufacturing will have to learn not only manufacturing skills but skills such as programming smart machines, smart products and services, sensor calibration and interfaces in addition to other soft skills requirements. Not only these skills have to be learnt but must be continuously updated by learning, training, and education. In short, these engineers will have to take responsibility for their own contribution and will be held accountable for the quality and quantity they produce; therefore, they must continuously train and retrain themselves in the skill set required for Industry 4.0. The engineer’s job itself will also have a component of continuous innovation built into it, because routine jobs will be automated. Likewise, continuous learning and teaching will have to be built into the job profiles of the engineers. Industry 4.0 initial implementation will be prevalent in the developed countries where there would be the rapid growth of older population. The continuous training the old engineers in the new age skills of Industry 4.0 will be a major adaptability training challenge for the organizations.

4.5 Practical Lesson 5: Managing stress

Industry 4.0 by virtue of digitalisation will change the modern working conditions in industrial settings [35]. The engineers working in an Industry 4.0 set up will have a high degree of human-machine interaction [3]. This may impact the psychosocial factors and engineer’s health [36, 37]. Working in a highly automated environment will increase mental workload rather than a reduction [36]. In a recent study on human-machine interaction, it was found that job stressors in a highly automated environment were due to poor usability, technical problems, reduced situation consciousness and increased requirement on engineers to carry out cognitive overloaded tasks. They further state technical issues such as breakdown or slowdown were the major stressors when engineers were not qualified to attend those [36]. Likewise, in an automated manufacturing environment the engineers are required to continuously indulge in supervisory monitoring, consequently, the cognitive demand among engineers will be increased in highly automated manufacturing environments such as Industry 4.0 [37, 38]. “Vertical integration” in Industry 4.0 will result in the integration of various functional departments in the organization. As each department, in the organization wants to optimise their own interest thus, this could be a major source of stress for the engineers[39]. In horizontal integration, the stressors would be the integration of various partnering organizations. In end-to-end integration technical aspects such as machine to machine integration, customer need analysis, product-to-service integration [40] may cause engineer stress. The engineers in three form of integration will rely on technology to accomplish tasks, achieve the objectives, and ultimately carry out the work [41]. The dependence of technology is to extend their capabilities, but it will also result in making engineers vulnerable. The human limitations which is very well explained by bounded rationality, cognitive overload theory and human interruption theory to make a point as to why productivity due to technology usage cannot be infinite. Once the optimum level is traversed, it will result in information overload, system functionality overload, and communication overload creating immense stress for the engineers using such a system. Consequently, the engineers who adapt themselves to managing stress will have the opportunity to work effectively in Industry 4.0 environment.

4.6 Practical Lesson 6: Working in teams

Teamwork is common in organizations and over time the work teams have become an intricate [42]. A hallmark of effective teams is that they are self-correcting, flexible, adaptable, and cohesive. They also hold shared thinking patterns of their job, objectives, and teammates. In Industry 4.0, most of the works will be done in teams or groups. In other words, it would be a knowledge intensive teamwork which would be a collaborative process where in engineers would use their distinctive and knowledge-sharing to achieve a common result. The knowledge activities within the team would be acquiring knowledge, information sharing, knowledge combination, knowledge generation, knowledge implementation and knowledge amendment. In Industry 4.0 there would be extensive usage of knowledge intensive teams and therefore, engineers will have to adapt to these activities in all three forms of integration. Vertical integration in Industry 4.0 will want members from different functional department to work as a team. In addition, there would be separate teams for each prominent tasks within the organization because Industry 4.0 will dissolve the conventional hierarchal structures , within the organization and instead will encourage multidisciplinary teams with a common goal. In a survey conducted among the representatives of Industry, it was found that teamwork will be more significant in Industry 4.0. Horizontal integration in industry 4.0 will cause the teams external to the organization and within the partnering organization to come together for carrying out a task. For the success of horizontal integration, teams from different partnering organization with different organizational culture [35] [34] should adapt and work together in a cohesive manner to achieve common objectives. Typical end-to-end integration teams would be technical, customer need analysts, product to service teams. This will be a complex amalgamation of team members from various functional disciplines operational in a dynamic manner throughout the life cycle of a product or service. Thus, the engineers in Industry 4.0 work environment will have work in teams and learn to adapt in teamwork, with members from different cultures.

5.0 PROPOSED CONCEPTUAL MODEL :

Industry 4.0 consists of three types of the integration the "vertical", "horizontal", and "end-to-end integration". The three types of integration create challenges for engineers to carry out day to day duties. An engineer will have to adjust to the work in accordance with the needs of Industry 4.0 in the three dimensions of integration. if it adapts on interpersonal, dealing with emergencies and unexpected circumstances, solving problem creatively, continuous learning training and education, managing work stress and working in teams. Fig. 1 depicts the conceptual model of engineer's adaptability. Interpersonal adaptability is important for the engineers to carry out day to day task in an efficient manner [18]. In the context in Industry 4.0 future research should be directed to explore the different dimensions of interpersonal adaptability. The dimensions might be different because of the stakeholders in "vertical", "horizontal", and "end-to-end integration" in Industry 4.0 might be dissimilar requiring diverse interpersonal strategies. Due to "vertical", "horizontal", and "end-to-end integration", there will be unexpected events in which are complex. To cite an example an unexpected event in the cybersecurity of the electronically integrated elements [43]. The complexity is because most of the systems in Industry 4.0 have a self-regulating element for the proper operation of various types of integration [44] and therefore, the unexpected events which may surface are not something which can be handled with reasonable prudence. An engineer must decide based on few facts, therefore decision making and handling unexpected events in Industry 4.0 is going to be a challenge and interesting area for future research. Industry 4.0 products are smart and manufactured in a “smart factory” with self-regulating components due to the development in artificial intelligence and advanced computing [45, 46]. Therefore, most of the problems which are of mundane nature will be solved by the “built-in self-regulating elements” of the machines [47]. The problems which are left with for human intervention will be complex, multidisciplinary, ill-defined, unusual, and which computer algorithms are unable to solve. These problems will have to be solved in a creative manner. Future research may be directed in evaluating existing creative problem-solving methods for suitability to solving Industry 4.0 problems e.g. C-K theory [48] or finding new methods which may helpful of Industry 4.0. The skill, training and education requirement for Industry 4.0 are diverse and will change with the context of the application [8]. Future research may be directed on how to engage or motivate engineers in a continuous learning cycle for the success of Industry 4.0 projects. Research on curriculum design for specific skill courses in Industry 4.0 will help students to acquire Industry 4.0 skills are specific as well as conceptually sound. Therefore, designing and teaching these skills in a short span is a challenge for the organization as well as service providers. There are many stress management models [49] and future research should examine the applicability of these models in Industry 4.0 environment, because, the stressors in Industry 4.0 environment will be complex and different compared to other environments [7, 8]. Teamwork will be a vital factor for the success of Industry 4.0 initiatives [8]. Future research may study theoretical models for working effectively on the complex problems of Industry 4.0. Research can also be directed to study one to one as well as one to group interactions to study the “group dynamics” for the complex problems in Industry 4.0.

Fig. 1: Proposed Conceptual Model of Engineers Adaptability in Industry 4.0

6. IMPLICATION FOR INDIAN ENGINEERING INDUSTRIES :

The human resource department in the organization must be geared up for the “digital transformation” of the organization. One of the major challenges would be how would an engineer adapt to the architecture of “vertical”, “horizontal” and “end-to-end integration” of Industry 4.0? These lessons satisfy the needs of “human resource managers” who are considered by the organisation to ensure that overall engineers are harmonized with the macro-level needs of the business. This study unearths six practical lessons which engineer must adapt when Industry 4.0 is implemented. The organization can use these dimensions for recruiting, assessment, and training. The primary use of these practical lessons will be training engineers to use the new technology. Industry 4.0 is primarily be implemented primarily in the developed countries such as Germany, UK, US where the labour market is skewed towards the ageing population, therefore, this tool can be used as guiding aid to train the engineers in specific skill set, older engineers are deficient. Another significant factor to consider is the stress on the engineers considering the rapid throughput rates due to the implementation of "vertical", "horizontal" and "end-to-end integration". This will be significant because older engineers in these organizations will have to train to manage these stress else the consequences would be devastating. As a further part of this study, organizations can develop items for each broad dimension of engineer adaptability. They can further tailor these items to the needs of the organization. Also, depending on the type of organization the weighting scheme for these dimensions should be decided. The weighting for a manufacturing and service organization will be different. Likewise, the weighting scheme will vary within each type e.g. in service it may vary between healthcare and education. The summation of scores of each dimension should be multiplied by appropriate weights for each dimension to assess the total adaptability of engineers. These dimensions can further be used for recruitment, assessment, and training needs of the engineers. Assessment of engineers should be carried out on all dimensions and structured training program can be developed to manage the existing talents onboard by giving them specific capsule training on each dimension for improving the efficacy of the training program. While acquiring talent on board the new engineer may be subjected to structured evaluation in these dimensions to select the finest among the existing pool of talents.

7. CONCLUSIONS :

Industry 4.0 is oriented towards total automation and data interchange between various elements in the "manufacturing systems" and other functions of organizations. Industry 4.0 is a "joint optimization" between "socio-technical" systems. The engineers being a key human to implement Industry and the role of engineers in the success of Industry 4.0 is extremely important for the successful application of Industry 4.0. This study explored the dimensions on which the engineers must adapt so that their skills and ability matches the requirements of knowledge society due to the application of Industry 4.0. Besides a conceptual framework is also developed which will help organizations to evaluate & train engineers in the proposed dimensions to make Industry 4.0 a success. Being a literature review article, it has limitations such the database explored in the study. In addition, the exclusion of non-English language literature could also have to be accounted in future studies.

REFERENCES :

[1] Sony, M., & Naik, S. (2019). Ten Lessons for managers while implementing Industry 4.0. *IEEE Engineering Management Review*, *47*(2), 45–52.

[2] Xu, L. Da, Xu, E. L., & Li, L. (2018). Industry 4.0: state of the art and future trends. *International Journal of Production Research*, *56*(8), 2941–2962.

[3] Sony, M., & Naik, S. (2019). Key ingredients for evaluating Industry 4.0 readiness for organizations: a literature review. *Benchmarking: An International Journal*, *27*(7), 2213–2232. https://doi.org/https://doi.org/10.1108/ BIJ-09-2018-0284

[4] Saldivar, A. A. F., Li, Y., Chen, W., Zhan, Z., Zhang, J., & Chen, L. Y. (2015). Industry 4.0 with cyber-physical integration: A design and manufacture perspective. In *Automation and computing (icac), 2015 21st international conference on* (pp. 1–6). IEEE.

[5] Cheng, G.-J., Liu, L.-T., Qiang, X.-J., & Liu, Y. (2016). Industry 4.0 development and application of intelligent manufacturing. In *Information System and Artificial Intelligence (ISAI), 2016 International Conference on* (pp. 407–410). IEEE.

[6] Hirsch-Kreinsen, H. (2014). Welche Auswirkungen hat" Industrie 4.0" auf die Arbeitswelt? WISO direkt (12/2014), pp. 1-4. Available at: http://libraryfes.de/pdf-files/wiso/11081.pdf (27.01.2015).

[7] Frey, C. B., & Osborne, M. A. (2017). The future of employment: how susceptible are jobs to computerisation? *Technological forecasting and social change*, *114*, 254–280.

[8] Bonekamp, L., & Sure, M. (2015). Consequences of Industry 4.0 on human labour and work organisation. *Journal of Business and Media Psychology*, *6*(1), 33–40.

[9] EEPC. (2020). *Indian Engineering Electrifying Growth*. Retrieved from http://www.eepcindia.org/download/IndianEngineeringBrochure-200819124444.pdf

[10] Ford, M. R. (2009). *The lights in the tunnel: Automation, accelerating technology and the economy of the future*. Acculant Publishing.

[11] Bowles, J. (2014). The computerisation of European jobs–who will win and who will lose from the impact of new technology onto old areas of employment. *Bruegel blog*, *17*.

[12] Brynjolfsson, E., & McAfee, A. (2014). *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*. WW Norton & Company.

[13] Maier, A., & Student, D. (2014). MD in Germany. *Manager Magazin*, *12*(2014), 92–98.

[14] Fettig, K., Gačić, T., Köskal, A., Kühn, A., & Stuber, F. (2018). Impact of Industry 4.0 on Organizational Structures. In *2018 IEEE International Conference on Engineering, Technology and Innovation (ICE/ITMC)* (pp. 1–8). IEEE.

[15] Porter, M. E., & Heppelmann, J. E. (2014). Wie smarte Produkte den Wettbewerb verändern. *Harvard Business Manager*, *12*(2014), 34–60.

[16] Fraunhofer, I. A. O., & Ingenics, A. G. (2014). Industrie 4.0–Eine Revolution der Arbeitsgestaltung. Wie Automatisierung und Digitalisierung unsere Produkte verändern werden. Available at: http://www. ingenics.de/de/news/aktuelles/industrie40_ergebnisse.php

[17] Michaels, G., Natraj, A., & Van Reenen, J. (2014). Has ICT polarized skill demand? Evidence from eleven countries over twenty-five years. *Review of Economics and Statistics*, *96*(1), 60–77.

[18] Charbonnier-Voirin, A., & Roussel, P. (2012). Adaptive performance: A new scale to measure individual performance in organizations. *Canadian Journal of Administrative Sciences/Revue Canadienne des Sciences de l'Administration*, *29*(3), 280–293.

[19] Borman, W. C., & Motowidlo, S. M. (1993). Expanding the criterion domain to include elements of contextual performance. *Personnel Selection in Organizations; San Francisco: Jossey-Bass*, 71.

[20] Schuh, G., Gartzen, T., Rodenhauser, T., & Marks, A. (2015). Promoting work-based learning through industry 4.0. *Procedia CIRP*, *32*, 82–87.

[21] Agostini, L., & Filippini, R. (2019). Organizational and managerial challenges in the path towards Industry 4.0. *European Journal of Innovation Management*, 22(3), 406-421.

[22] Pulakos, E. D., Arad, S., Donovan, M. A., & Plamondon, K. E. (2000). Adaptability in the workplace: Development of a taxonomy of adaptive performance. *Journal of applied psychology*, *85*(4), 612.

[23] Sony, M., & Mekoth, N. (2014). The dimensions of frontline employee adaptability in power sector. *International Journal of Energy Sector Management*, *8*(2), 240–258. https://doi.org/10.1108/ijesm-03-2013-0008

[24] Sony, M., & Mekoth, N. (2015). Fleadapt scale: a new tool to measure frontline employee adaptability in power sector. *International Journal of Energy Sector Management*, *9*(4), 496–522.

[25] Baldassari, P., & Roux, J. D. (2017). Industry 4.0: preparing for the future of work. *People & Strategy*, *40*(3), 20–24.

[26] Kazancoglu, Y., & Ozkan-Ozen, Y. D. (2018). Analyzing Workforce 4.0 in the Fourth Industrial Revolution and proposing a road map from operations management perspective with fuzzy DEMATEL. *Journal of Enterprise Information Management*, *31*(6), 891–907.

[27] Hecklau, F., Galeitzke, M., Flachs, S., & Kohl, H. (2016). Holistic approach for human resource management in Industry 4.0. *Procedia CIRP*, *54*, 1–6.

[28] Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. *British journal of management*, *14*(3), 207–222.

[29] Liao, Y., Deschamps, F., Loures, E. de F. R., & Ramos, L. F. P. (2017). Past, present and future of Industry 4.0-a systematic literature review and research agenda proposal. *International journal of production research*, *55*(12), 3609–3629.

[30] Sony, M., & Mekoth, N. (2018). A qualitative study on electricity energy-saving behaviour. *Management of Environmental Quality: An International Journal*, 29(5), 961-977.

[31] Özdemir, V. (2018). The dark side of the moon: the internet of things, industry 4.0, and the quantified planet. *Omics: a journal of integrative biology*, *22*(10), 637–641.

[32] Sony, M., Antony, J., & Douglas, J. A. (2020). Essential ingredients for the implementation of Quality 4.0. *The TQM Journal*, 32(4), 779-793.

[33] Wulfken, B. T., & Müller, E. (2017). How to improve employee education—Methodological approach to structure specialist and interdisciplinary requirements. In *Industrial Engineering and Engineering Management (IEEM), 2017 IEEE International Conference on* (pp. 130–134). IEEE.

[34] Schallock, B., Rybski, C., Jochem, R., & Kohl, H. (2018). Learning Factory for Industry 4.0 to provide future skills beyond technical training. *Procedia Manufacturing*, *23*, 27–32.

[35] Sony, M. (2018). Industry 4.0 and lean management: a proposed integration model and research propositions. *Production & Manufacturing Research*, *6*(1), 416–432.

[36] Körner, U., Müller-Thur, K., Lunau, T., Dragano, N., Angerer, P., & Buchner, A. (2019). Perceived stress in human-machine interaction in modern manufacturing environments–results of a qualitative interview study. *Stress and Health*, *35*(2), 187-199.

[37] Wixted, F., Shevlin, M., & O'Sullivan, L. W. (2018). Distress and worry as mediators in the relationship between psychosocial risks and upper body musculoskeletal complaints in highly automated manufacturing. *Ergonomics*, 1–15.

[38] Berg, A., Buffie, E. F., & Zanna, L.-F. (2018). Should we fear the robot revolution?(The correct answer is yes). *Journal of Monetary Economics*, *97*, 117–148.

[39] Hirschi, A. (2018). The fourth industrial revolution: Issues and implications for career research and practice. *The career development quarterly*, *66*(3), 192–204.

[40] Chen, Y. (2017). Integrated and intelligent manufacturing: Perspectives and enablers. *Engineering*, *3*(5), 588–595.

[41] Graetz, G., & Michaels, G. (2018). Robots at work. *Review of Economics and Statistics*, *100*(5), 753–768.

[42] Mathieu, J. E., Wolfson, M. A., & Park, S. (2018). The evolution of work team research since Hawthorne. *American Psychologist*, *73*(4), 308.

[43] Thames, L., & Schaefer, D. (2017). *Cybersecurity for Industry 4.0*. Springer.

[44] Lu, Y. (2017). Industry 4.0: A survey on technologies, applications and open research issues. *Journal of Industrial Information Integration*, *6*, 1–10.

[45] Burke, R., Mussomeli, A., Laaper, S., Hartigan, M., & Sniderman, B. (2017). The smart factory: Responsive, adaptive, connected manufacturing. *Deloitte Insights, August*, *31*.

[46] Wang, S., Wan, J., Zhang, D., Li, D., & Zhang, C. (2016). Towards smart factory for industry 4.0: a self-organized multi-agent system with big data based feedback and coordination. *Computer Networks*, *101*, 158–168.

[47] Benešová, A., & Tupa, J. (2017). Requirements for Education and Qualification of People in Industry 4.0. *Procedia Manufacturing*, *11*, 2195–2202.

[48] France, L. (2017). Innovation and creativity management: The C-K theory. *Leyton Innovation, Technology*. Retrieved from https://www.leyton.com/blog/?p=1745-innovation-creativity-management-c-k-theory

[49] Holton, M. K., Barry, A. E., & Chaney, J. D. (2016). Employee stress management: An examination of adaptive and maladaptive coping strategies on employee health. *Work*, *53*(2), 299–305.

****