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Development of a Framework for Adoption of Industry 4.0

[1]Mr. Deependra Yadav, [2]Dr.Manish Gangil

M.Tech.Scholar[1], Professor[2]
Department of Mechanical Engineering, RKDF, University Bhopal, (M.P.) India.
[1]yadavdeependra36@gmail.com, [2]rkdfbhojpal@gmail.com,

ABSTRACT:

With the development in industrialization, sustainability has emerged as a major issue in the global market. Ignorance of sustainability issues in any organization leads to huge financial losses and market reputation. With the development of new technologies developed economies have achieved sustainability in their industry sectors due to strong infrastructure. However, the adoption levels of sustainability practices in emerging economies are still limited. The current manufacturing trend in Industry 4.0 offers new key technologies e.g. cyber-physical systems, IoT (Internet of Things), additive manufacturing and big data analytics which are under the umbrella of Industry 4.0 known as key technologies for 4th industrial revolution. These new technologies are contributing to sustainability in a direct or indirect way. Identification of different enablers is necessary as it facilitates the adoption of sustainability practices in Industry 4.0. The present study aimed at the development of sustainability practices of a framework for of Industry 4.0.

1. Introduction

The manufacturing world is currently experiencing serious disruption on many facets of production due to integration of digital technologies into every business functions. This transformation to Industry 4.0 (I 4.0) involves different but interrelated elements such as technology, organization, people, government and legal issues [1] It is insisted in the prior literature that substantial amount of efforts are required at all levels of business functions as well as at government level to successfully transform the manufacturing organizations to I 4.0 [2] The present research studies focus on the prerequisites and requirements of I 4.0 adoption. However, the readiness assessment or maturity level measurement studies are limited. Further, there is a dearth of comprehensive assessment model which accommodates I 4.0 awareness aspect and the model that measures the adoption level of several key technologies such as 3DP, BT, *ARNR,* AI/ML and simulation tools. The focus of existing maturity models are primarily on the organizations from developed countries and/or organizations that are more matured for I 4.0. There is little evidence regarding the maturity models that are particularly designed for evaluating readiness of organizations from developing nations like India. Therefore, to address this research gap, the current study proposes an I 4.0 assessment framework in the form of maturity model. The proposed 'I 4.0 Maturity Model' is empirically grounded and technology-focused for assessing the readiness of Indian manufacturing organizations.[3]

2. Expected Benefits (Industrial Performance Metrics) from Adoption of Industry 4.0 Technologies

2.1 Measures of Variables

In order to understand the relationship between I 4.0 technologies and expected benefits (industrial performance), the constructs of I 4.0 technologies and expected benefits were obtained from the variables is listed.[4]

Industry 4.0 Technology (Independent variables)

Tl. Collaborative Robots

T2. M2M and M2H communication

T3. Digital platforms

T4. ERP, MES, CRM and PLM tools

T5. Bar code, QR code, RFID T6. Intelligent sensors & PLCs T7. AR, VR and MR

T8. Additive manufacturing: 3DP T9. Mobile devices and Wearable's

TIO. Smart Product

TIL Block chain Technology

T12. Cloud computing

T13. loT and loS

T14. Big data and Simulation tools

T15. AI, ML and DL

T16. Industrial Cyber security

Expected Benefits (Dependent variables)

Bl. Increase in productivity and production efficiency

B2. Reduction in costs (like production, logistics, labour, material and maintenance costs etc.)

B3. Enhanced process visualization and control

B4. Higher flexibility (product /operational)

B5. Improved product quality

B6. Reduction in time to market for new products

B7. Better customer service and customer satisfaction

B8. Compensate for the lack of a skilled manpower

B9. Efficient asset/resource utilization (human capital, energy, water and raw material)

BIO. Improving sustainability

B11. Safer workplace conditions and improved work-life Balance

B12. Growth in market share and to obtain competitive advantage

B13. Increased profit and fast Return on Investment

This list includes I 4.0 technologies which are discussed in I 4.0 readiness study. The 16 technologies were selected for this study because these technology factors are contributing higher (cumulative weight around 0.5) than other factors in readiness measurement study. Based on literature review and expert opinion, four formative constructs of I 4.0 technologies were formed. The expected benefits were synthesized into main categories using Principal Component Analysis (PCA). The PCA technique is useful to obtain broader performance metrics. Refer in Section 2.1 for various I 4.0 technologies and expected benefits. The next section elaborates the PCA of expected benefits variables to obtain main performance metrics (industrial performance main constructs).[5]

2.3 Respondents, Sample Size and Data Distribution

The survey was administrated in the manufacturing organizations operating in India. The manufacturing organizations included in this study compliance the research criteria such as 'organizations are working in manufacturing sector and it is in process of adopting digital technologies'. The study has gathered 174 valid responses from various manufacturing sectors as discussed in section 2.2. The rule of thumb for sample size calculation is 10 times number of indicators in larger construct of the model. The most complex and larger construct in the proposed research model is I 4.0 Base Technology (IBT) having 5 formative indicators. The sample size of 50 would be enough for this type of studies however current study has sample size of 174 which is much higher than the recommended.[6]

After initial statistical analysis it was found that the results of "Kolmogorov- Smimov and Shapiro-Wilk"(KS and SW) test violate the assumptions of data normality ($p < 0.05$) for all indicators of exogenous constructs. Also the measures of variables in the research model include formative and reflective constructs. The suitable approach to analyse the relationship between I 4.0 technologies and expected benefits is decided according to above mentioned conditions of the data. The recommended technique is Partial Least Square Structural Equation Modeling (PLS- SEM) when there is mixture of formative and reflective constructs and data violates normal distribution. The next sections expounds on the research methodology adopted to analyse the data.[7]

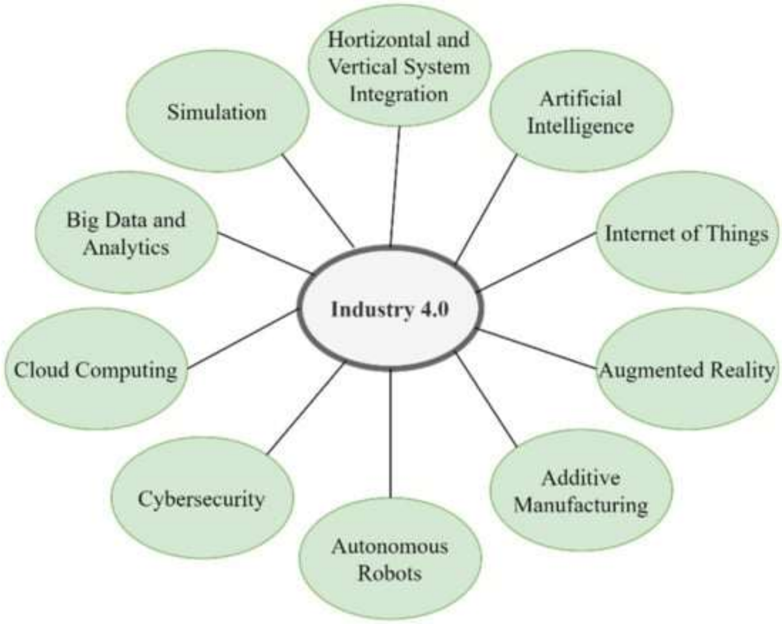

Fig.1 Respondents, Sample Size and Data Distribution [1]

3. A Framework and Roadmap for Adoption of Industry 4.0 in Indian Manufacturing Organizations Challenges

Based on the experience gained during case studies (Chapter 4), findings from survey and a study conducted to reveal expected benefits from adoption of emerging technologies a framework for adoption of I 4.0 is proposed. Figure 6.5 illustrates a framework for adoption of! 4.0.

The proposed framework consists of four attributes i.e. I 4.0 technologies, readiness factors, barriers to I 4.0 and expected benefits (performance metrics). The adoption of I 4.0 technologies expected to deliver operational and product/service related benefits along with secondary benefits like sustainability and work-life balance. But there are some factors that are crucial while adopting I 4.0, so these factors or barriers should also be included in the framework of! 4.0. [8]

Fig.2 Changelings for Industry 4.0 [2]

4. Scale of Performance Benefit Metrics and I 4.0 Technology Adoption

The developed framework for adoption of 14.0 involves four important attributes and design principles of 4.0. The manufacturing firms can utilize this framework and roadmap for systematic adoption of 4.0. The framework will guide organizations to implement not only smart manufacturing technologies but also the adoption of a complete set of emerging technologies including product/service oriented technologies and I 4.0 base technologies. The framework exhibits level of complexity of technology implementation. The framework and roadmap proposed in this study can be used as capability maturity model, one which can provide guidelines and prerequisites on the path of 4.0. Findings of study advocate that organizations should not limit adoption of technologies related to smart manufacturing such as sensors/PLCs, RFID, Bar codes, ERP and MES. As depicted in the framework, digital platforms for customers and suppliers, loT, Block chain, AI, end-to-end integration of software are frontiers regarding the complexity of adoption of I 4.0. Organizations that master these front-end technologies can capture competitive advantage in this UVCA world. These higher-end technologies enable real-time monitoring and control through Big Data and Analytics which eventually delivers operational benefits, virtualization and manufacturing flexibility. [9]

The step-by-step approach to I 4.0 adoption is suggested for organizations so as to reap maximum benefits from this novel concept. Three phase model including Envision, Enable, and Enact phases are recommended for the successful dissemination of I 4.0 vision in the organization. It is necessary for organization to prepare company-specific vision for I 4.0 based on organizational requirements. Further organization should split whole I 4.0 vision into small projects. This may help organizations to handle and subsequently leverage and disseminate I 4.0 aspects in supply chain network.[10]

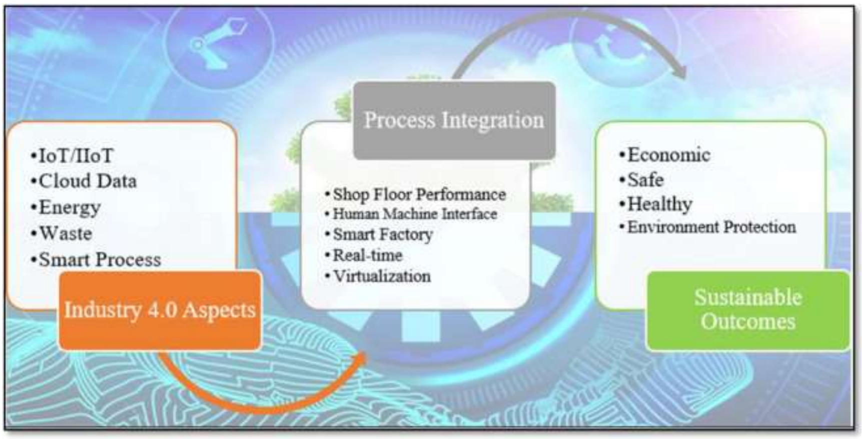

Fig.3 Understanding the Adoption of Industry 4.0 Technologies in Improving Environmental Sustainability [3]

Conclusions

In framework for adoption of I 4.0 is developed for Indian manufacturing organizations, which is one of the research objectives of this study. To develop a framework for I 4.0, it is essential to divulge the perception of Indian manufacturing organizations towards industrial performance from I 4.0 technologies. Therefore in initial part of this chapter, this study demonstrates how Indian manufacturing organizations perceive the potential contribution of I 4.0 technologies for industrial performance. The model explores relationship between I 4.0 technologies and expected benefits for 'operational', 'products and services' and 'sustainability and resources' aspects. It also revealed from assessment of model that the secondary benefits like product/services and sustainability could be thought off after achieving operational performance. A few I 4.0 technologies are positively strongly associated with productivity and cost reduction benefits while other technologies are at its early adoption stage hence not clear about expected benefits related to environmental concerns and leT enabled product services. This study contributed to state-of-the-art in a way to show how emerging technologies of I 4.0 are used and perceived in emerging economy context.

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