



## Development of Industry 4.0 Maturity Model and Exploratory Case Studies

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### **Abstract**

The manufacturing global is presently experiencing severe disruption on many facets of manufacturing due to integration of virtual technology into each commercial enterprise capabilities. This transformation to Industry 4.0 (I 4.0) involves one of a kind however interrelated elements along with era, business enterprise, humans, authorities and prison issues (Keskin et al., 2018). It is insisted in the earlier literature that great quantity of efforts are required at all levels of business features as properly as at government degree to efficiently remodel the manufacturing agencies to I 4.0 (Oesterreich and Teuteberg, 2016). The gift research research consciousness at the conditions and necessities of I 4.0 adoption. However, the readiness evaluation or adulthood degree dimension studies are limited.

### **1. Introduction**

Further, there is a dearth of complete evaluation model which contains I four.0 attention component and the model that measures the adoption stage of numerous key technologies which includes 3DP, BT, ARNR, AI/ML and simulation gear. The cognizance of present maturity models are frequently at the agencies

from developed international locations and/or groups that are more matured for I 4.0. There is little proof regarding the maturity models that are specifically designed for evaluating readiness of corporations from developing nations like India. Therefore, to cope with this research gap, the contemporary observe proposes an I 4.0 evaluation framework within the form of maturity model. The proposed 'I 4.0 Maturity Model' is empirically grounded and technology-cantered for assessing the readiness of Indian production agencies. The version comprises of 34 adulthood gadgets unequally labelled into 7 dimensions. The model is tested and proven in Indian manufacturing corporations. The consequences of exploratory case research conducted in 3 specific enterprise sectors particularly Auto - ancillary, Food processing and Electronic Products Manufacturing companies are supplied in this chapter.

### **1.1 Phases of Development of Industry 4.0 Maturity**

#### **Model**

For the development of adulthood version, the systematic stepwise method IS appropriately advanced based on the pointers suggested by way of Hevner et al. (2004) and Becker et al. (2009).

These step-by-step tips to increase a maturity version have a strong theoretical history from the design science research. The research framework observed in this observe and levels of adulthood model development. The studies framework accommodates a multi-methodological method to develop a adulthood model such as literature assessment, comparison of present maturity models, professionals' interview, modeling and conceptual design, testing and validation of the version in actual-existence application. The research framework has 3 awesome stages including understanding approximately I 4.0 concept, centre development phase - conceptual modelling, virtual evaluation form, trying out, validation, and the medical documentation and implementation in a real-existence production environment. The system followed within the framework is an iterative process that helped in evaluating, refining and improving the maturity model. The system of improvement of the maturity version IS divided into three stages as explained in next sub-sections.



**Fig. 1 Characteristics of Industry 4.0**

## **2. Building a Thorough Understanding of I 4.0 Concepts and Identifying the Underlying Problems in its adoption**

It is imperative for manufacturing organizations to recognize approximately the capabilities required triumphing over the I 4.0 visions in a systematic manner. Currently I 4.0 concepts is in the preliminary ranges of its development, therefore, there are no agreements or preferred consensus a few of the researchers and practitioners about the elements of I 4.0 (Akdil et al., 2018). It is likewise cited in the literature that the idea isn't always absolutely and actually understood by the pinnacle control of numerous agencies (Schumacher et al., 2016). Therefore, it is imperative in this have a look at to exactly understand the area complexities and thereby simply define the components of I 4.0 and its attributes.

### **2.1 Reviewing and Comparing the Existing Maturity Models**

The literature became very well explored to acquire numerous adulthood models associated with I 4.0 area. Thereafter those recognized maturity models have been completely analysed, categorized and in comparison according to pre-decided evaluation standards and characteristics of fashions as stated in section 2.9. The execs and cons of the models are indexed and the suitability of those fashions is evaluated for proposed model, domain (manufacturing or carrier sectors) and geographical context (especially for developing nations). The particular assessment of those research helped in to determine the concepts

relevant to construct the version shape together with assessment techniques (qualitative or quantitative or mixed), wide variety of adulthood ranges (from degree 1-lowest to 5-highest adulthood), dimensions (minimal three dimensions

## **2.2 Fuzzy AHP Approach**

When selection-making involves complicated troubles and human judgment, Analytic Hierarchy Process (AHP) is taken into consideration as a big approach inside the selection sciences (Saaty 1980). However, AHP is frequently criticized for now not completely revealing human questioning which is at large represented by linguistic and vague patterns (Cheng 1996). Further AHP do not computes results while facts are indistinct or vague. To counter these problems concerned inside the AHP, extant literature gives Fuzzy technique for choice making problems (jakhar and Barua, 2014). The idea proposed below Fuzzy set has functionality to paintings with unclear or grey statistics and when uncertainty in the decision making exists. Due to simplicity and closeness to human judgment Fuzzy AHP (FAHP) approach became famous among.

calculations are mechanically achieved and adulthood results are numerically and graphically displayed on a dashboard. This dashboard portrays the adulthood ratings for every measurement and maturity gadgets in each numeric and graphical shape (radar charts). This facilitates the company to interpret the effects incredibly. The definitions of the maturity levels and their characteristics also are listed for equipped reference of the organization. Lastly, the

complete outcomes of the evaluation criteria in all dimensions are provided and could help as the foundations for strategic choices and development of projects.

## **2.3 Testing and Validation Phase**

The version is finally examined in the actual-lifestyles environment and comments from the specialists are looked for its practicability. Based on the reaction from the practitioners and customers of the adulthood version, certain changes within the adulthood model are carried out. The 3 iterations have been finished to finalize maturity objects and dimensions and this iterative manner helped to improve the quality, usability and validity of the adulthood version. This version is in the end carried out in the actual-existence scenario and empirically examined in diverse groups.

## **4. Forming a Structure of Model**

The proposed 'Industry 4.0 Maturity Model' includes the maximum giant 7 maturity dimensions namely, 'People and Culture', 'I 4.0 Awareness', 'Organizational Strategy', 'Value Chain and Processes', 'Smart Manufacturing Technology', 'Product and Services oriented Technology' and 'I 4.0 Base Technology'. The measurement objects protected in every evaluation dimension are derived from the preceding studies and recognized with assist of experts inside the domain. The subsequent sub-phase discusses the maturity dimensions and its attributes to acquire I 4.0 imaginative and prescient.



#### **4.1 People and Culture**

For successful operationalization of I 4.0, 'People and Culture' is an essential component due to the fact of inimitable cost and strength of human inside company (Bibby and Dehe, 2018). Many layout science studies underline the largest challenge for any transformation endeavour is 'cultural behaviours and mind-set of human beings' earlier than 'Technology'. The high quality mindset of humans and right digital culture permit the adoption of I 4.0 (Geissbauer et al., 2016). The organizations that embrace persistent changes and imbibe innovation culture will have high chances to be triumphant in the virtual transformation.

Industry 4.0 encompasses several moves beyond manufacturing or operational sports together with worker making plans, leaders' dedication and control help when you consider that this transition to I 4.0 revives whole commercial enterprise procedures right from fee creation to value proposition. The achievement inside corporation largely depends on how well the top control defines, leads and communicates the transformation (Geissbauer et al., 2016). The significance of human involvement within the I 4.0 sports is also mentioned in wide variety of current adulthood fashions (Lichtblau et al., 2015; Gokalp et al., 2017; Bibby and Dehe, 2018). Therefore the dedicated teams to adopt I 4.Zero initiative is utmost crucial in upcoming transformation. Moreover, new work profiles and task skills will emerge due to

digitalization of operational technologies. For companies building records analytical capabilities, improving virtual capabilities and qualification might be essential in destiny. The present workforces do not own required virtual capabilities and qualification at this point of time. The employees' educational capability, vocational competency and other vital human resource requirements are huge elements at the same time as evaluating the capability of businesses to I 4.0 (Akdil et al., 2018). The readiness objects derived from the extant literature are listed as follows: management support, non-stop development subculture, committed groups, and virtual capabilities and qualification.

#### **4.2 Industry 4.0 Awareness**

The survey have a look at presented through Chengula et al. (2018) reviews that the companies demands for a commonplace set of guidelines because of a lack of clarity concerning I 4.0 concepts. There is a strong want to make personnel of corporation aware regarding how an company IS changing inside the contemporary virtual transformation. Further enterprise must make certain participation of their employees with most comprehension. Currently many companies do not recognize the blessings related to the high-quit technologies and most of them still didn't examine the ROI and value-benefit ratio. The knowledge and attention of personnel about the blessings of emerging technologies considerably influences economic investment and stage of implementation (Gokalp et al., 2017). Few research additionally mentioned that, there

may be low recognition among the corporations especially employer running in growing nations (Kamble et al., 2019b). The inadequate familiarity with topic no longer only affects the organizations' capacity to respond to the virtual changes but also delays their preparedness degree to extra quantity. This is extraordinarily relevant for the businesses from growing nations wherein there's low stage of industrialization, loss of automation and lack of competencies within the group of workers. Within the context of I 4.0 focus, the following evaluation objects are derived from the literature: familiarity with I 4.0 concept, sensitivity towards impact of virtual transformation, usefulness of the concept for enterprise performance and preparedness for the transformation.

### **4.3 Organizational Strategy**

When evaluating principal technological changes it is crucial to increase clear strategic goals, timeframes, conversation and supporting enablers that are carefully aligned into overall enterprise targets to make sure fulfillment (Gokalp et al., 2017). The digital revolution is not an IT mission in isolation; the modifications will fundamentally transform business fee advent and value capture inside a organization's products, services and operations. It impacts how and wherein value is captured. It requires a 'whole of enterprise' method to the making plans and strategic attain of the era. In extant literature, several adulthood studies within the domain of I 4.0 have advocated organizational method as a critical driving force (Mittal et al., 2018).

Although I 4.0 emphasis extra on to the technological aspects and actual - time communiqué, corporation alignment in phrases of virtual vision, robust long time and short term strategic desires, comprehensive roadmap, properly idea out financial making plans and investments are important for the company maturing towards I 4.0 (Bibby and Dehe,2018). Arguably, application of I 4.0 would be different for each business enterprise from contextual and operational factor of view. Additionally the scope of I 4.0 can be extraordinary across corporations or even can be tailored primarily based on the organization's approach (Keskin et al., 2018). It is crucial for businesses to enhance their competencies regarding the customization and personalization of products as properly as services. Therefore it's far vital to assess the readiness of an corporation on the issue that the organization's potential to combine clients' want and/or possibilities inside the product development and manufacturing levels.

The collaboration with academic institutes might be useful for employees of organization to beautify know - how concerning the concept and exchanging the views with different contributors at some stage in workshops and meetings. Next, a good way to transform the organization, dynamic collaboration with exclusive stakeholders would play big position in maturation. The employer's dedication to address the information or facts without published paper is taken into consideration as enabler to I 4.0. The readiness items derived from the extant literature are

listed as follows: digital imaginative and prescient and roadmap, customer integration, collaboration, zero paper method and economic investments.

#### **4.4 Four Value Chain and Processes**

Industry 4.0 is referred to a community of factories and businesses in the value supply chain. The integration of complete supply chain is a basis for I four.0. It isn't sufficient to digitalize or include technological transformation inside the manufacturing unit or business or business enterprise in silos, however there may be want of dynamic collaborative efforts to combine and interconnect the organizations within the deliver chain community with similar kind of skills. For this the based integration of agency with its suppliers and customers is vital to gain advantages out of this novel idea. Before going for the horizontal integration of price chain community, the companies ought to act on the vertical integration of IT systems proper from quit – to - end IT enabled product making plans and designing, to productions planning, to production to pre/publish income activities. It is essential to map each method or hobby of enterprise digitally inside the virtual surroundings. Additionally, the price-added strategies must be incorporated across the organizational architecture in a scientific way (Gokalp et al.,2017). The dimension items derived from the literature are: digitalization of vertical and horizontal value chain, actual-time monitoring and manipulate, end-to-end IT enabled planning, digitalization of production gadget

#### **4.5 Smart Manufacturing Technology**

The measurement 'Smart production era' is a crucial size for enabling I 4.0 for any business enterprise. Although most of the technology are to be had to digitalize keep floor operations but it is vital to verify the organization's readiness for digitalization of production technique and its connectivity. For digitalizing manufacturing strategies, companies need to appoint shrewd sensors, actuators and PLCs on machines and devices. The machines and humans communicate and change every records or statistics without problems through software program systems. This will permit employer in a decision making at system manipulate degree, production manage level and company control stage (Gokalp et al., 2017). Autonomous robots and AGVs are needed to make system to paintings smart and automating the activities of manufacturing operation. The technologies which assist the business enterprise to enhance its manufacturing operations and enable them to connect with gadget and human beings at various hierarchical tiers with ease are required to be evaluated in context of I four.0 (Bibby and Dehe, 2018). The 'smart manufacturing era' measurement consists of the assessment of adoption stage of I 4.0 thru digital manufacturing and virtual operations context. Within the outlook of digitalization of producing process and self-reliant activities inside the keep- floor, the following dimension items are identified: Cobots; Bar code, QR code, RFID and RTLS; clever sensors, actuators,



embedded systems and PLCs; software Systems like ERP, MES, CRM and PLM; M2M and H2M communiqué; and virtual structures.

#### **4.6 Product and Services Oriented Technology**

In previous few years, the era diffusion throughout numerous sectors is growing very rapid; particularly the virtual technologies are embedded into the merchandise so as to supply smart merchandise with excessive degree of customization (Kagermann et al., 2013). These merchandise have ICT add-on functionalities, virtual features and are augmented with the digital services. In different words, the products and services are not any longer remained as distinct commercial enterprise segments for company; instead it can be seen now as an incorporated product-service enterprise which can generate sales through facts- pushed offerings. Businesses have an possibility to generate cost out of those clever merchandise through collection of information in its whole lifestyles cycle, feedback, pre/post income offerings, product development and extraordinarily customization of products (Lichtblau et al., 2015). For instance, the cellular phones, televisions and smart watches have the virtual abilities to provide records-driven offerings based totally at the information series and gives customized digital offerings. Other technologies such as 3 - D printing, ARNR and cell devices provide fairly customized merchandise to clients and flexibility in the offerings. Even thru Block chain generation, the automatic and

interconnected community may want to be established which will enhance the transparency within the e-value chain appreciably (Kamble et al., 2019a). Within the context of digitalization of merchandise, augmentation of offerings directly to products and effectiveness and transparency of supply-chain offerings, the following era would play critical position whilst comparing the adulthood level of an business enterprise on the direction to I 4.0: Smart Product, 3DP, BT, ARNRIMR and Mobile gadgets and Wearable.

#### **5. Industry 4.0 Base Technology**

'Industry 4.0 base generation' measurement is a central component for I 4.0, and this important size at once influences different dimensions or criteria. The most enormous challenges in adoption of I 4.0 are not predominantly in the usage of the isolated and range of technologies in the corporations, but alternatively it's far within the amassing, storing and analyzing the information to deliver data-pushed services (Lichtblau et al., 2015). The current literature encouraged that the IoT/loS, Cloud production, Big Data analytics and AI are critical enablers for I 4.0 realization. Due to over growing connectivity among the IT and OT, the structures and machines are at risk of the cyber-assault therefore the industrial cyber security is need of an hour for any organisation to shield statistics, intellectual assets and comfortable its humans, structures and machines (Kagermann et al., 2013). Therefore inside the context of faraway connectivity, cloud

based manufacturing, information analytics and cyber safety, the following generation might play important function at the same time as evaluating the maturity stage of an employer: Cloud computing, IoT/loS, BD and Simulation tools, AIIMLIDL and Industrial Cyber safety.

## 5.2 Importance Weight of Maturity Items and Dimensions

The proposed adulthood model includes 34 adulthood dimension items unfold across 7 I 4.0 dimensions. The top cognizance of this adulthood version is on emerging technologies in addition to the vital factors of firms consisting of techniques, people and tradition, focus approximately the idea, usefulness and sensitivity for I 4.0 transformation.

## Conclusions

This study contributes to the literature in the domain of I 4.0 by using presenting a maturity evaluation framework inside the shape of a version to help companies to examine their readiness for I 4.0. The evaluation framework includes 34 maturity gadgets which can be recognized from the extant literature and identified thru experts' opinion. An assessment shape is designed systematically to are seeking for the responses from the respondents towards each maturity item.

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