PRE-STANDARDIZATION STUDY REPORT
ON
SMART MANUFACTURING

November 2018

मानक : पथप्रदर्शक

Bureau of Indian Standards

Pre-Standardization Study Report

on

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November 2018
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SMART INFRASTRUCTURE SECTIONAL COMMITTEE, LITD 28
ELECTRONICS AND INFORMATION TECHNOLOGY DIVISION COUNCIL

BUREAU OF INDIAN STANDARDS

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Bureau of Indian Standards further places on record the able and timely support and guidance of DDG (Standardization) Dr. R. K. Bajaj to understand the finer nuances of the Global Standardization Paradigm and bring comprehensive nation centric requirements on the standardization platform.

Bureau of Indian Standards.

Disclaimer

Foreword

Today, we are witnessing something unique, something spectacular as we are all adopting new ways of working, new methods of communication, new systems of manufacturing generally under the nomenclature of Fourth Industrial Revolution. It is again going to change the system, processes and methods of industrial manufacturing and the way business/ organizations are organized, interact and operate.

For this 4^{th} Industrial Revolution to be safe, to be available to all globally and yield benefits to humanity at large, to achieve the universal sustainable development goals, Standards will play a great role. Standards are more important than ever now. For systems to be safe and secure regulations have to be in place; standards facilitate regulators.

India being a developing nation, still has a long way to go in this arena. Although some of the industries in India have progressed technologically, there are still some sectors that need digital reforms. For an instance, **automotive industry** in India is highly automated, connected, and integrated. **Pharmaceutical companies** have also begun to switch to new technologies. Certain industries like textile, plastics processing & converting, metal and printing are still using legacy systems which make it difficult to migrate to new technologies, still they are trying to cope with advanced technologies. But hopefully, with the help of skilled manpower, and government initiatives like Samarth Udyog, these industries will be able to join the Industry 4.0 revolution soon. For this 4^{th} IR to be safe, to be available to all globally, to yield benefits, to humanity at large, to serve SDGs Standards will play a great role.

This pre-Standardization study report prepared by BIS is an effort to understand the Smart Manufacturing in the context of contemporary societal & business challenges and leveraging latest technological innovations in a sustainable manner for the stakeholders of the ecosystem. It reflects the existing work done, work being done in the field of Smart Manufacturing and identifies the gap areas that need to be addressed to enable comprehensive transformation of the ecosystem and benefit the society, at large. This report is intended to help develop the Road Map for Standardization in the field of Smart Manufacturing for the future work of BIS along with some pointers for developing conducive policies & regulations to enable rapid adoption & proliferation of the Smart Manufacturing paradigm that shall help consolidate India's leadership in the Global Manufacturing Ecosystem.

I hope all stakeholders will use it as required

Surina Rajan
Director General,
Bureau of Indian Standards

About BIS

Bureau of Indian Standards (BIS) is the National Standard Body of India established under the BIS Act 1986 for the harmonious development of the activities of standardization, marking and quality certification of goods and for matters connected therewith or incidental thereto.

BIS has been providing traceability and tangibility benefits to the national economy in a number of ways - providing safe reliable quality goods; minimizing health hazards to consumers; promoting exports and imports substitute; control over proliferation of varieties etc. through standardization, certification and testing.

Keeping in view, the interest of consumers as well as the industry, BIS is involved in various activities as given below:

a. Standards Formulation
b. Product Certification Scheme
c. Compulsory Registration Scheme
d. Foreign Manufacturers Certification Scheme
e. Hall Marking Scheme
f. Laboratory Services
g. Laboratory Recognition Scheme
h. Sale of Indian Standards
i. Consumer Affairs Activities
j. Promotional Activities
k. Training Services, National & International level
l. Information Services

BIS has its Headquarters at New Delhi and its 05 Regional Offices (ROs) are at Kolkata (Eastern), Chennai (Southern), Mumbai (Western), Chandigarh (Northern) and Delhi (Central). Under the Regional Offices are the Branch Offices (BOs) located at Ahmedabad, Bangalore, Bhubaneswar, BhopaSl, Coimbatore, Dehradun, Faridabad, Ghaziabad, Guwahati, Hyderabad, Jaipur, Kochi, Lucknow, Nagpur, Parwanoo, Patna, Pune, Rajkot, Raipur, Durgapur, Jamshedpur and Vishakhapatnam, which offer certification services to the industry and serve as effective link between State Governments, industries, technical institutions, consumer organization etc. of the respective region.

For formulation of Indian Standards, BIS functions through the Technical Committee structure comprising of Sectional Committees, Subcommittees and Panels set up for dealing with specific group of subjects under respective Division Councils. The committee structure of BIS seeks to bring together all those with substantial interest in particular project, so that standards are developed keeping in view national interests and after taking into account all significant viewpoints through a process of consultation.

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Background

Industry 4.0 and smart manufacturing are topics, which are gaining attention globally. Many countries across the globe have initiated work and standardization effort in this direction. Manufacturing setups, machine builders, factories globally have stepped up effort in adopting next generation technologies for becoming ready for Industry 4.0.

India too in recent years is evaluating these next generation technologies and moving in the direction of adoptions.

BIS, has also initiated the standardization activities in these upcoming trends and technologies making it easier for Indian stakeholders to adopt these technologies in their machines, factories and manufacturing setups.

When BIS initiated standardization in the field of Smart manufacturing, a Task Group on "Smart Manufacturing" had been constituted under the Smart infrastructure panel of BIS to prepare a Pre-Standardization study report which will provide a comprehensive "Actionable Insights for Smart Manufacturing in India" to develop the required Roadmap supported by Policies, Regulations and Standards for the smart manufacturing paradigm.

The Task Group was assigned the following tasks:

a. Review the current market trends and technology trends in context of the Smart Manufacturing Paradigm globally.
b. Undertake a comprehensive enumeration of the challenges & requirements to address the current imperatives of the Indian Manufacturing Ecosystem.
c. Provide specific Actionable Insights to enable the Indian Manufacturing to evolve into a globally competitive Manufacturing Destination.
d. Review all candidate Reference Frameworks, Architectures, ICT Technologies and Standards developed either by Global, Regional, National SDOs or any Industry consortia or fora.
e. Recommend the India appropriate Reference Frameworks & Architectures and relevant Technologies & Standards for the Manufacturing Ecosystem of the Nation

The responsibility of the task group was to recommend an India appropriate comprehensive strategy and approach for Smart Manufacturing, which shall enable optimization of business processes, optimization of smart ICT infrastructure and technologies being deployed in the Manufacturing Ecosystem which in turn will bring down the CAPEX and OPEX in deployment of the Smart Technologies in the Manufacturing. This shall be achieved by proposing a comprehensive strategy to address India Specific problems, challenges and imperatives along with a Standardized Framework for improving the operational & financial efficiency of manufacturing activities.

Presently the task group on Smart manufacturing has been transformed to a working group named "Smart manufacturing working group" (LITD 28/WG 3) under the Smart infrastructure sectional committee (LITD 28).

Context

Industry seeks to operate safe, secure, sustainable, energy efficient and environmentally conscious manufacturing operations that produce competitive quality products in their target markets. There are published regulations in many geographic markets for many of these system attributes and International Standards available for all of them. In order for the manufacturing operations to meet the regulations and standards required, all functional elements of the total system need to integrate and interoperate together to achieve a desired system goal derived from the manufacturing business policies and their implementation strategies:

a. Safety
b. Security
c. Sustainability
d. Energy Efficiency
e. Environment
    - Materials
    - Green House Gas
    - Carbon Foot Print
    - Waste/ Recycle
f. Health and Safety

Imperatives

The review of the trends and initiatives contextualized with the ground realities in the nation has given the following initial imperatives:

a. Though globally Smart Manufacturing is being seen as leveraging ICT & automation to improve the overall efficiency in manufacturing ecosystem, which may be sufficient for the developed nations, however, India's imperatives are much diverse and complex than simply this.

b. India is at the cusp of major economic revolution. India is ranked second behind China in manufacturing competitiveness and has already started narrowing the gap over last few years. "India's rich talent pool of scientists, researchers and engineers as well as its large, well-educated English-speaking workforce and democratic government regime make it an attractive destination for manufacturers".

Scope

This pre-standardization study report on Smart Manufacturing reflects the existing work done, work being done in the field of Smart Manufacturing and identifies the gap areas with respect to standardization in this field.

This report covers:

- The current market and technology requirements in the context of Smart Manufacturing.
- The Smart manufacturing initiatives in India and across the globe and standardization in the field
- Smart Manufacturing process/ecosystem in India.

This report also recommends an India appropriate comprehensive strategy and approach for Smart Manufacturing in India and the report would serve as roadmap for India for Standardization in the field of Smart Manufacturing.

Smart Manufacturing Ecosystem - Global View

Advanced manufacturing (US)

In the US, several initiatives such as the Smart Manufacturing Leadership Coalition (SMLC) or the Industrial Internet Consortium (IIC) are promoting the concept of advanced manufacturing, which is based on the integration of advanced new technologies such as IoT into the manufacturing area to improve produced goods and manufacturing processes.

A significant amount of study and work has been done by the Advanced Manufacturing Partnership (AMP), a steering committee reporting to the US President's Council of Advisors on Science and Technology. Their recommendations describe the basis of the initiatives sponsored by the Advanced Manufacturing Office (AMO) and the various innovation hubs being established around the US.

The concepts behind advanced manufacturing are also often referred to as smart manufacturing or smart production and focus on smart products and objects in the production environment, which support product design, scheduling, dispatching, and process execution throughout factories and production networks in order to increase efficiency and enable individualization of products.

e-Factory (Japan)

The e-Factory concept from Japan is achieving an advanced use of the industrial internet with regard to both manufacturing control and data analytics, with the aim of effecting an optimization of productivity and energy conservation. The e-Factory approach helps to make the factory truly visible, measurable and manageable with the help of emerging technologies.

As more data than ever before will be generated by equipment, devices, sensors and other ICT equipment, big data analytics will have the power to dramatically alter the competitive landscape of manufacturing in the future. Combining manufacturing control and big data analytics through the industrial internet will produce huge opportunities in all manufacturing areas.

Moving from current implementation to future creations, the next generation e-Factory is targeting the entire networked manufacturing supply chain, its operational efficiency and its innovation, by considering and integrating information technologies as well as enabling a continuous improvement of physical systems and pushing forward collaboration between humans. The potential significance of the next generation e-Factory approach is indeed broad: enabling technologies include sensing, smart robotics, automation of knowledge work, IoT, cloud services, 3D printing, etc. These are applied to respond to future market needs and to implement new business models.

To realize the next generation e-Factory approach, a multi-company organizational structure has been formed to enable cooperation between assemblies of companies. This partner alliance is aimed at joint product development, manufacturing, and marketing, as well as solution innovation for the entire supply chain. Meanwhile, governmental organizations have also launched investigation and studies to support the industrial companies undertaking such activities.

Intelligent Manufacturing (China)

China is pushing forward its Intelligent Manufacturing initiative, which will drive all manufacturing business execution by merging ICT, automation technology and manufacturing technology. The core of the idea behind Intelligent Manufacturing is to gain information from a ubiquitous measurement of sensor data in order to achieve automatic real-time processing as well as intelligent optimization decision-making. Intelligent Manufacturing realizes horizontal integration across an enterprise's production network, vertical integration through the enterprise's device, control and management layers, and all product lifecycle integration, from product design through production to sale.

The target of Intelligent Manufacturing is to improve product innovation ability, gain quick market response ability and enhance automatic, intelligent, flexible and highly efficient production processes and approaches across national manufacturing industries. Furthermore this initiative focuses on the transformation of manufacturing towards a modern manufacturing model involving an industry with a high-end value chain. It thereby promotes advanced manufacturing technology, the transformation and upgrading of traditional industries and the nurturing and development of strategic emerging industries.

To implement this goal, China has established the Made in China 2015 strategy, which aims at innovation, quality and efficiency in the manufacturing domain.

Digitizing European Industry (Europe)

Industry is one of the pillars of the European economy – the manufacturing sector in the European Union accounts for 2 million enterprises, 33 million jobs and 60% of productivity growth. Manufacturing accounts for 16% of Europe's GDP. The sector is responsible for 64% of private sector Research & Development expenditure and for 49% of innovation expenditure in Europe. Europe stand on the brink of a new industrial revolution, driven by new-generation information technologies such as the Internet of Things (IoT), cloud computing, big data and data analytics, robotics and 3D printing. These technologies open new horizons for industry to become more adventurous, more efficient, to improve processes and to develop innovative products and services. Recent studies estimate that digitization of products and services can add more than EUR 110 billion of annual revenue to the European economy in the next five years. European industry is strong in digital sectors such as electronics for automotive, security and energy markets, telecom equipment, business software, and laser and sensor technologies. Europe also hosts world-class research and technology institutes. The European Commission launched on 19 April 2016 the first industry-related initiative of the Digital Single Market package. Building on and complementing the various national initiatives for digitizing industry, such as Industrie 4.0, Smart Industry and l'industrie du futur, the Commission will take actions along 5 main pillars. These include use of policy instruments, financial support, coordination and legislative powers to trigger further public and private investments in all industrial sectors and create the framework conditions for the digital industrial revolution. The mid-term review of the Digital Single Market strategy focuses on digitizing the European industry-oriented actions, aiming to manage digital transformation of our society and economy. Overall, Europe plans to mobilize up to EUR 50 billion of public and private investments in support of the digitization of industry.

- EUR 37 billion investment to boost digital innovation.
- EUR 5.5 billion national and regional investments in digital innovation hubs.
- EUR 6.3 billion for the first production lines of next-generation electronic components.
- EUR 6.7 billion for the European Cloud Initiative.

The Digitising European Industry initiative aims to reinforce EU's competitiveness in digital technologies and to ensure that every business in Europe –which ever the sector, wherever located, whatever the size - can fully benefit from digital innovation. To reach this goal the European Commission put in place five key action lines where important progress has already been made. In this factsheet you can find a summary of the initiative, why it is needed and how Europe is progressing on its implementation. Almost two years after its launch, this factsheet offers an overview of the main action lines proposed and the achievements so far.

- Member States are joining forces in a **common European platform**, co-investing into further development of digital innovations and reinforcing EU competitiveness.
- EU investments in Public-Private Partnerships for Research and Innovation are contributing to build key digital technologies and their integration in future digital industrial platforms.
- The EU is supporting a network of Digital Innovation Hubs covering all regions to help companies –especially SMEs– make the most of digital opportunities.
- When necessary, EU regulations are being reviewed to make them fit for the digital age.
- Several EU actions are supporting the development of digital skills to ensure all Europeans count with the necessary skills to live and work in an increasingly digital society.
- The Digitising European Industry brochure offers more details on the progress made and the need to keep working together for the digital future of EU industry.

Industrie 4.0 (Germany)

Industrie 4.0, the 4th industrial revolution, is enabled by a networked economy and powered by smart devices, technologies and processes that are seamlessly connected. The vision for the 4th industrial revolution is for cyber-physical production systems which provide digital representation, intelligent services and interoperable interfaces in order to support flexible and networked production environments. Smart embedded devices will begin to work together seamlessly, for example via the IoT, and centralized factory control systems will give way to decentralized intelligence, as machine-to-machine communication hits the shop floor.

The Industrie 4.0 vision is not limited to automation of a single production facility. It incorporates integration across core functions, from production, material sourcing, supply chain and warehousing all the way to sale of the final product. This high level of integration and visibility across business processes, connected with new technologies will enable greater operational efficiency, responsive manufacturing, and improved product design.

While smart devices can in many ways optimize manufacturing, they conversely make manufacturing far more complex. The level of complexity this creates is immense, because it not only concerns isolated smart devices, but involves the whole manufacturing environment, including various other smart devices, machines and IT systems, which are interacting across organizational boundaries.

Industrie 4.0 and its underlying technologies will not only automate and optimize the existing business processes of companies; it will also open new opportunities and transform the way companies interact with customers, suppliers, employees and governments. Examples of this are emerging business models based on usage and metering.

To push forward Industrie 4.0 applications, there exists a broad community encompassing industrial associations in Germany such as VDMA, Bitkom, and ZVEI, large companies and research organizations. Driven by this community, governmental initiatives such as national or regional studies and research programmes have been launched, in addition to the efforts being undertaken by industrial companies.

New Industrial France (France)

The "New Industrial France" or NFI in French- "Nouvelle France Industrielle" was launched in April 2015 to succeed the reindustrialization of France. The New Industrial France programme is based on 9 industrial solutions that provide real-world responses to key economic and social challenges. These solutions will position French businesses on tomorrow's markets in a world in which digital technology is erasing the boundary between industry and services. Large-scale means have been put in place to support ambitious industrial projects and step up the deployment of the goods and services of tomorrow.

a. Data economy
b. Smart objects
c. Digital trust
d. Smart food production
e. New resources
f. Sustainable cities
g. Eco-mobility
h. Medicine of the future
i. Transport of tomorrow

https://www.economie.gouv.fr/files/files/PDF/web-dp-indus-ang.pdf

In October 2017, the "French Fab" brand was launched to represent the French ecosystem of industry in France and abroad. Whatever the size of the companies, from medium size companies to international groups, all of them focus on local expertise, factories, and engineering offices and are open to great evolutions based on digital, new technologies or green economy. All of them have a long-term project and are involved either in manufacturing or providing services, to build the Industry of the future "à la Française".

https://www.lafrenchfab.fr/#Partenaires will provide you with the list of the French FAB partners.

Smart Industry (Netherlands)

The Smart Industry (SI) initiative was launched in November 2014 by the government and industry stakeholders. The objectives are to strengthen the Dutch manufacturing industry position and increase industrial productivity. Smart Industry is structured around three main action lines that seek to capitalize on existing knowledge, accelerate and introduce ICT in companies and strengthen knowledge, skills and ICT conditions.

- The first action line concerns the use of existing knowledge and focuses on the gathering and dissemination of knowledge to businesses. This is carried out by providing companies with technological and market understanding, best practices and tools. Specific activities cover presentations, a website, online training modules and business team trainings.
- The second action line, acceleration through field labs, is assumingly the most visible part of SI. It seeks to create national and regional ecosystems and interrelated networks of companies and knowledge institutions with a basis in SI principles. The field labs present practical environments for design, testing, experimentation and deployment of technology solutions. The labs work as operational environments where people can join for discussion, meetings etc. It is basically a location with a programme that is made up of multiple try-out innovation projects and planned training within projects.
- The third action line is of a more long-term nature and aims to improve knowledge, skills and ICT conditions. In terms of knowledge, it is focused on strengthening R&D incentives in field labs and to develop a long-term SI research agenda together with top sectors and universities. Human capital conditions are sought upgraded through adapting relevant educational courses and programmes – ranging from primary education to scientific education and dual education - to the needs of SI. It seeks to offer modular educational blocks and to organise courses on sustainable production. ICT conditions are targeted by a vision to develop an increasingly solid and secure ICT infrastructure and by a research programme for the development of software tools that cover chain collaboration, interoperability and standardization.

https://ec.europa.eu/growth/tools-databases/dem/monitor/sites/default/files/DTM_Smart%20Industry%20v1.pdf

Others

Several other European countries have launched or are launching national initiatives to stimulate Industry 4.0 implementation. These initiatives include the following:

- Italy – Intelligent Factories , Industria 4.0
- Spain: Industria Conectada 4.0
- Slovakia – Smart Industry
- Austria: Plattform Industrie 4.0
- Poland: "Initiative for Polish Industry 4.0 – The Future Industry Platform"
- Portugal "Indústria 4.O"
- Lithuania: "Pramonė 4.0"
- Hungary:"IPAR 4.0 National Technology Platform"

Initiatives in India

SAMARTH Udyog (Smart Advanced Manufacturing and Rapid Transformation Hub): https://samarthudyog-i40.in/

SAMARTH Udyog Bharat 4.0 is an Industry 4.0 initiative of Department of Heavy Industry, Ministry of Heavy Industry & Public Enterprises, Government of India under its scheme on Enhancement of Competitiveness in Indian Capital Goods Sector. It aims to facilitate and create eco system for propagation of Industry 4.0 set of technologies in every Indian manufacturing by 2025, be it MNC, large, medium or small scale Indian company.

SAMARTH Udyog encompasses manufacturers, vendors and customers as the main stakeholders. The experiential and demonstration centers for Industry 4.0 have been proposed to spread awareness about I4.0 amongst the Indian manufacturing industries. Four centers of I4.0 having a unique identity for spreading awareness and branding have been sanctioned under SAMARTH Udyog. It is emphasized that these centers would have resource sharing, common platform of industry 4.0 and network each other's resources so that the utilization of resources is maximized.

Mandated guidelines for CEFC under SAMARTH Udyog:

- Awareness campaigns on Industry 4.0,
- Training for Master Trainers,
- Active Participation Provisions for Start-up/ incubators,
- Hand-holding of SMEs to plan and implement relevant Industry 4.0 projects to be done through consultancy services on chargeable basis,
- Collaborating with neighborhood Universities for student training/internship programs,
- Involving industry in SPV membership model for sustainability,
- Participating in a Government formed platform for Industry 4.0 on common agenda
- To make adequate provisions for e-waste management,
- Involving as many clusters of Capital Good as possible

Mission of SAMARTH Udyog initiative is:

Pier I: Awareness and Demystification: Developing programmes, programme contents, institutions, cadre of experts and cooperation to create awareness about Industry 4.0 in Indian manufacturing.

Pier II: Experience and Demo Centres: Creation of country vide network in every manufacturing cluster to provide demonstration, experience and adoption of Industry 4.0.

Pier III: Training and Skills: Creation of training programmes, training content, methodology, trainers, institutions and support mechanisms to train Indian manufacturing personnel in new trades required by induction of Industry 4.0.

Pier IV: Industry and Academia: Developing network and cooperation between industry and academia with the objective of graduate students having knowledge and skills required in the industry for Industry 4.0. This includes setting up start-ups, incubators, bridge courses, recognition of prior learning and continued learning.

Pier V: Engineering Research and Applicable of Industrial I 4.0 Technologies: Creation of institutional capacities, projects, programmes and IPR for new applications of Industry 4.0 required by the country, which are different than the one adopted by the West.

Pier VI: International Cooperation: Creation of cooperation and programmes for by directional flow of knowledge and skills between India and the rest of the world related to Industry 4.0.
Composition:

- Like rest of the world all stake holders whether in line function or in support function of manufacturing and software based in India are proposed to be brought together in grand alliance on Industry 4.0. Their cooperation will be based on mutually beneficial agenda in the verticals specified as above in the vision and mission statements. Typical examples are :-
- Government: Central and State Departments dealing with industry such as Department of Industrial Policy & Promotion, Department of Heavy Industry, Department of Small & Medium Enterprises, Department of Information Technology, Ministry of Science & Technology, Ministry of Skill Development & Entrepreneurship, Ministry of Food Processing, Ministry of Petroleum etc.
- Industrial Associations & individual industrial units: Confederation of Indian Industry, Federation of Indian Chambers of Commerce & Industry, Automation Association of India etc. etc.
- Institutions: IITs, IISc, CMTI, NITs, DRDO institutions, CSIR institutions, Departmental institutions, private industrial R&D institutions etc.
- Support organizations: VDMA, GITA, NRDC etc.

Four CEFC (Common Engineering Facility Center) Projects are:

1. Kirloskar Centre for Learning in Industry 4.0
2. IITD-AIA Foundation for Smart Manufacturing: http://www.iafsm.in/
3. I4.0 India at IISc Factory R & D Platform
4. Smart Manufacturing Demo & Development Cell at CMTI

The Indian Institute of Technology (IIT) Delhi and the Automation Industry Association (AIA) entered into a partnership in May 2017, to help India become a leading global player in the area of smart manufacturing. Both IITD and AIA signed an MOU for setting up a National Common Engineering Facility Center (CEFC) for Smart Technology Enabled Manufacturing.

AIA also signed a MoU with the Automotive Component Manufacturers Association (ACMA) to extend the benefits of the CEFC to its member companies.

Global Standardization Initiatives

Standards Developments Organizations have a history of developing and supporting standards for multiple products, systems and services deployed within a manufacturing system domain, but to date these standards have been focused on specific equipment, processes and management systems and have been developed within individual technical committees. Within a smart manufacturing domain there is an opportunity for better integration of individual systems and more sharing of information across the manufacturing business to facilitate overall system performance and reduce the integration costs experienced by manufacturers when purchasing multiple equipment and systems from independent vendors. This improved integration and data exchange may also foster the development of new manufacturing processes and services. There exist several standardization roadmaps from different National Committees highlighting the standards supporting smart manufacturing.

IEC SyC SEG 7 Smart manufacturing

SEG 7 was created by IEC SMB with the following scope:

- Expand on the market relevance and business drivers, identified in the SG 8 report, taking into account other SDO initiatives and national programs;
- Provide an inventory of existing standards and current standardization projects under the management of IEC, ISO and other SDO;
- Invite the cooperation of ISO, JTC1/WG10 (presently JTC 1/SC 41), IEEE, consortia, and other organizations to assist in mapping smart manufacturing activities that are closely related, and to participate in the activities of the proposed SyC;
- Expand on the definition of common value chains within a smart manufacturing enterprise, as identified in SG 8, and identify associated use cases which will assist in determining the state of the art in the industry, and the identification of potential gaps where IEC standardization is needed with respect to smart manufacturing;
- Establish an initial roadmap of smart manufacturing standardization, architecture and prospective standardization and conformity assessment projects to be conducted by the SyC member TCs and partners;

SEG 7 initiated the following three task teams.

Task Team 1 - Standard maps: Review the standard portfolios and gap analysis in the ISO SAG report, the SG8 report and the NIST report and I4.0 report; and make recommendations on how to reconcile the available data and propose organization for a combined roadmap and dashboard.

Task Team 2 - Use cases: To collect available UCs from existing standards activities and make recommendation as to how UCs may be collected and entered into the UCM and tied to the standards and architecture models.

Task Team 3 - Models and Architectures: To provide details on potential relevant architecture models for consideration by the joint TC 65 / ISO/TC 184 team resulting from the ISO TMB report.

Task Team 3 has developed a Unified Reference Model – Map and Methodology (URM-MM). The URM-MM aims to provide a map and methodology to be referred to by SDOs and standard users in an open eco-system development. The map and methodology illustrate a procedural guide that enables users to identify specific use cases that then link the relevant international standards to existing models. The process appears to be the basis of a required navigation tool for the smart manufacturing system. The current model illustrates an example of one use case in the sub domain of "production" and SEG 7 Task Team 3 was asked to conduct a second pilot with a use case that addressed other functional areas within smart manufacturing as a further proof of concept.

Product Data Dictionary Expansion

All manufacturing tasks are consistent in their use of physical, human, and information resources. These resources can be modeled in a database that reflects and describes the significant attributes of the resources which signify availability, capacity, and performance capability of the system. By expanding the attributes in the model to include dynamic data from the entities as they are put to work in the system a complete digital model of a manufacturing system can be developed, modeled and simulated prior to investment in the procurement of the resources. Expansion of the CDD function as a basis for developing this modeling capability is a key requirement for the smart manufacturing domain standardization to deliver value to industry and national manufacturing programs. This work needs to be completed including an extension of the CDD coverage regarding the type and number of entities (products and concepts) capable of being modeled.

Wireless spectrum allocation

The SMB was requested by the former SG 8 to propose to ITU-R to reserve specific radio spectrum for use within Industrial Automation facilities. The required spectrum to be defined is a minimum of 80MHz in the range of 1.4 GHz to 6.0 GHz. The request was supported by the SMB and presented to ITU-R. The focus of this work was subsequently transferred by SEG 7 to SEG 8 / WG3. The SyC is expected to monitor SEG 8 activities and keep them informed of their requirements.

SEG 7 Final report: SEG 7 has held three plenary meetings and one ad-hoc meeting to prepare the final report and recommendations to IEC SMB.
As recommended by SEG 7, a new Systems committee named IEC SyC Smart manufacturing has been created under SMB with the following initial scope:

- To provide coordination and advice in the domain of Smart Manufacturing to harmonize and advance Smart Manufacturing activities in the IEC, other SDOs and Consortia.

The first meeting of the SyC Smart manufacturing is scheduled to be held during 6-7 November in Offenbach, Germany.

Standardization in Europe:

In Europe, there are three responsible organizations: CEN, CENELEC (Electrical Engineering) and ETSI (European Telecommunications Standards Institute). The standardization work is being driven forward by various technical committees of CEN/CENELEC:

- **CEN/TC 438 - Additive Manufacturing:** Standardization in the field of Additive Manufacturing (AM): The main objective of the committee is to standardize the processes of Additive Manufacturing, the test procedures, environmental issues, quality parameters and vocabularies. The new technical committee will have three main goals:
  - To provide a complete set of European standards, part of which will be developed based on the international standardization work of ISO;
  - To strengthen the link between European research programs and standardization in AM;
  - To ensure transparency and visibility of the European standardization in AM.

  For more information please click here

- **CEN/TC 310 - Advanced automation technologies and their applications:** Standardization in the field of automation systems and technologies and their application and integration to ensure the availability of the standards required by industry for design, sourcing, manufacturing and delivery, support, maintenance and disposal of products and their associated services.

  For more information about structure, work program and published standards please click here

- **CLC/TC 65X: Industrial-Process measurement, control and automation**
  To contribute, support and coordinate the preparation of international standards for systems and elements used for industrial process measurement, control and automation at CENELEC level. To coordinate standardization activities which affect integration of components and functions into such systems including safety and security aspects. This CENELEC work of standardization is to be carried out for equipment and systems and closely coordinated with IEC TC65 and its subcommittees with the objective of avoiding any duplication of work while honoring standing agreements between CENELEC and IEC.

  For more information please click here

In Germany, DIN (German Institute for Standardization) and DKE (German Commission for Electrotechnical, Electronic & Information technologies of DIN and VDE) are the main standardization bodies. Nowadays, almost 90% of standardization work is geared towards the European and international levels, with DIN and DKE organizing the entire process of standardization on the national level and ensuring German involvement in the European processes through the corresponding national committees (see Table below):

Table 1: Industrie 4.0: Relevant committees and consortia

National committees and consortia	Standards and specifications
CEN/CLC	EN Standards
ETSI	EN-Standards (SDR|VNF/Radio/4G, 5G/Security/M2M)
DIN/DKE	DIN SPEC 27070 Reference architecture of a security gateway for the exchange of industry dataand services DIN SPEC 16593-1RM-SA – Reference Model for Industrie 4.0 Servicearchitectures – Basic concepts of an interactionbasedarchitecture DIN SPEC 91345 Reference Architecture ModelIndustrie 4.0 (RAMI4.0) DIN SPEC 16592 Combining OPC UnifiedArchitecture and Automation Markup Language

VDI/VDE GMA	VDI/VDE 3682 Formalized process description VDI/VDE 3695 Engineering of facilities VDI 4499 Digital Factory VDI 5600 MES

DIN and DKE founded the Standardization Council Industrie 4.0 (SCI 4.0) 4 in conjunction with the industry associations BITKOM, VDMA and ZVEI. SCI 4.0 is responsible for orchestrating standardization activities and, in this role, acts as a point of contact for all matters relating to standardization in the context of Industrie 4.0. In collaboration with the Plattform Industrie 4.0, SCI 4.0 brings together the interested parties in Germany and represents their interests in international bodies and consortia. SCI 4.0 also supports the concept of practical testing in test centers by initiating and implementing new informal standardization projects tailored to meet specific needs. A list of standards published by CEN/CENELEC/DIN for smart manufacturing is available as Annexure to this report.

Standardization in USA:

In the USA, the Industrial Internet Consortium (IIC) is one of the most active and important industry forums in the area of Industrial IoT. IIC is an open membership organization, with 258 members as of 22 November 2016. The IIC was formed to accelerate the development, adoption and widespread use of interconnected machines and devices and intelligent analytics. Founded by AT&T, Cisco, General Electric, IBM, and Intel in March 2014, the IIC catalyzes and coordinates the priorities and enabling technologies of the Industrial Internet.

Though its parent company is the Object Management Group (OMG), the IIC is not a standards organization. Rather, the consortium was formed to bring together industry players — from multinational corporations, small and large technology innovators to academia and governments — to accelerate the development, adoption and widespread use of Industrial Internet technologies.

Specifically, the IIC members are concerned with creating an ecosystem for insight and thought leadership, interoperability and security via reference architectures, security frameworks and open standards, and real world implementations to vet technologies and drive innovations (called testbeds). The IIC Technology Working Group ratified Industrial Internet reference architecture in June 2015, which defines functional areas and the technologies and standards for them, from sensors to data analytics and business applications.

The development of testbeds to demonstrate the real-world implementation of Industrial Internet solutions is one of the goals of the IIC. As of September 2018, the Consortium has publicly announced twenty seven testbeds.

Two key documents that have been published by IIC are:

- The Industrial Internet Reference Architecture (IIRA)
- The Industrial Internet Security Framework (IISF)

These detailed documents have now become extremely important in the Industrial IoT space. We provide below a brief description of the two documents.

The Industrial Internet Reference Architecture (IIRA)

The IIRA is a standards-based open architecture for IIoT systems. The IIRA maximizes its value by having broad industry applicability to drive interoperability, to map applicable technologies, and to guide technology and standard development. The architecture description and representation are generic and at a high level of abstraction to support the requisite broad industry applicability. The IIRA distils and abstracts common characteristics, features and patterns from use cases defined in the IIC as well as elsewhere. It will be refined and revised continually as feedback is gathered from its application in the testbeds developed in IIC as well as real-world deployment of IIoT systems. The IIRA design is also intended to transcend today's available technologies and so can identify technology gaps based on the architectural requirements. This will in turn drive new technology development efforts by the industrial internet community.

The Industrial Internet Security Framework (IISF)

The purpose of the document, 'Industrial Internet of Things Security Framework' (IISF) is to identify, explain and position security-related architectures, designs and technologies, as well as identify procedures relevant to trustworthy Industrial Internet of Things (IIoT) systems. It describes their security characteristics, technologies and techniques that should be applied, methods for addressing security, and how to gain assurance that the appropriate mix of issues has been addressed to meet stakeholders' expectations.

The document is also a reference for the Industrial Internet Consortium's testbeds that already span verticals such as smart grid, transportation, industrial maintenance and others. The security evaluations of these testbeds will serve extremely useful in ensuring the end-to-end security of the testbeds.

An Industrial Internet of Things (IIoT) system exhibits end-to-end characteristics that emerge as a result of the properties of its various components and the nature of their interactions. The five characteristics that most affect the trust decisions of an IIoT deployment are security, safety, reliability, resilience and privacy. These five characteristics together define 'Trustworthiness' and they are referred to as key system characteristics. Others, for example, scalability, usability, maintainability, portability or composability may be important in general too but are not considered "key" in respect to trustworthiness.

Technology enablers for smart manufacturing

Automation, robotics has been around in manufacturing for decades. Today, with the Industrial revolutions 4.0, collaboration, digitization, optimizations are the new ways of manufacturing products. There are many technologies, which will act as enablers for making manufacturing smart.

Industrial IoT

Information – Internet of Things has grabbed the attention of consumers and data is playing a vital role in consumer IoT. In manufacturing too, Industrial IoT is becoming the talk of the town. The Industrial Internet of Things is changing value chain forever and leading companies to rethink their business models from the ground up.

With digitization, manufacturing industry in India is undergoing changes in all areas rights from machine development to factory shop floors. Companies have understood the importance of IT / OT convergence and many have already started taking steps in this direction. Automation has long changed manufacturing and digitization is further changing the way factories operate.

What does it mean?

Machines - For individual machines, Industrial IoT means closed-loop control in real time. It means implementing the latest software technology in greenfield and brownfield plants alike, opening up entirely new possibilities for analytics and control and allowing immediate feedback about asset performance.
Lines - With advanced edge computing, the technology enables central data acquisition for every module in a production line. Business intelligence and data historian features offer long-term trend analysis and forecast generation Plants and enterprises - Cloud computing delivers scalable and dynamic IT-enabled services. As the gateway to smart manufacturing, it connects smart machines and opens new windows of visibility into processes.

How it benefits?

Optimize asset utilization - More reliable business processes at maximum performance and minimum cost, highly flexible automation systems and optimal utilization of available resources,
Add sales potential - New business models such as pay-per-use, machine updates via software, higher availability through precise forecasting and analysis
Optimize service - Leverage data to improve processes, new service offerings such as remote maintenance, offer precise service level agreements

Standard associated –
IoT and related technologies - ISO/IEC JTC 1/SC 41
Industrial Internet Reference Architecture
Industrial Internet Security Framework
OneM2M Industrial Domain Enablement – Technical Report
ETSI remote industrial process control-https://www.etsi.org/technologies-clusters/technologies/internet-of-things

Digital Twin or Virtualization

Information – Virtualization allows descriptive models to be constructed in order to simulate the behaviour of the motion control system or control loops. This allows future challenges to be identified early. For optimum networking, machines must be equipped with semantic interfaces. These allow them to provide process data in high resolution for advanced analytics or to be integrated into functionally interlinked systems. Digital Twin provides a complete digital footprint of machines, enabling machine builders to detect physical issues sooner, predict outcomes more accurately, build better machines faster with superior quality, reduce time-to-market and costs. Virtualization is very powerful allowing visibility of machine operations as well as large interconnected manufacturing systems. By making virtual representation of product or process, Digital Twin is helping machine builders to save cost and time involved in building machines and software development. Digital Twin is a digital representation of a product, equipment or a process. Digital twin is essentially a combination of data and intelligence, representing the structure, behaviour, and context of a physical system of any type. Digital twin provides an interface that allows understanding the past and present operations of assets and helping predict the future. They help optimize the physical world and improve operational performance and business processes.

Examples – Virtualizing machines and factories on computers.

Standard associated –
Augmented Reality Framework: https://www.etsi.org/technologies-clusters/technologies/augmented-reality
Network Functions Virtualisation: https://www.etsi.org/technologies-clusters/technologies/nfv
5G: https://www.etsi.org/technologies-clusters/technologies/5g

Big Data analytics

Information – Big Data analytics is the process of collecting, organizing and analyzing large sets of data (called Big Data) to discover patterns and other useful information. Big Data analytics can help organizations to better understand the information contained within the data and will also help identify the data that is most important to the business and future business decisions. Analysts working with Big Data typically want the knowledge that comes from analyzing the data.

For most organizations, Big Data analytics is a challenge. Consider the sheer volume of data and the different formats of the data (both structured and unstructured data) that is collected across the entire organization and the many different ways different types of data can be combined, contrasted and analyzed to find patterns and other useful business information.

Examples – An interesting example comes from one of the biggest mobile carriers in the world. France's Orange launched its Data for Development project by releasing subscriber data for customers in the Ivory Coast. The 2.5 billion records, which were made anonymous, included details on calls and text messages exchanged between 5 million users. Researchers accessed the data and sent Orange proposals for how the data could serve as the foundation for development projects to improve public health and safety. Proposed projects included one that showed how to improve public safety by tracking cell phone data to map where people went after emergencies; another showed how to use cellular data for disease containment.

Standard associated –
ISO/IEC JTC 1/SC 32- Data management and interchange
ISO.IEc JTC 1/SC 42 – Artificial Intelligence

Pervasive computing

Information – Ubiquitous or Pervasive computing is a concept in software engineering and computer science where computing is made to appear anytime and everywhere. In contrast to desktop computing, ubiquitous computing can occur using any device, in any location, and in any format. A user interacts with the computer, which can exist in many different forms, including laptop computers, tablets and terminals in everyday objects such as a refrigerator or a pair of glasses. The underlying technologies to support ubiquitous computing include Internet, advanced middleware, operating system, mobile code, sensors, microprocessors, new I/O and user interfaces, networks, mobile protocols, location and positioning, and new materials.

Pervasive or Ubiquitous computing touches on a wide range of research topics, including distributed computing, mobile computing, location computing, mobile networking, context-aware computing, sensor networks, human–computer interaction, and artificial intelligence.

Artificial Intelligence

Information – Artificial intelligence (AI), sometimes called machine intelligence, is intelligence demonstrated by machines, in contrast to the natural intelligence displayed by humans and other animals. In computer science, AI research is defined as the study of "intelligent agents": any device that perceives its environment and takes actions that maximize its chance of successfully achieving its goals. Colloquially, the term "artificial intelligence" is applied when a machine mimics "cognitive" functions that humans associate with other human minds, such as "learning" and "problem solving".

The traditional problems (or goals) of AI research include reasoning, knowledge representation, planning, learning, natural language processing, perception and the ability to move and manipulate objects. General intelligence is among the field's long-term goals. Approaches include statistical methods, computational intelligence, and traditional symbolic AI. Many tools are used in AI, including versions of search and mathematical optimization, artificial neural networks, and methods based on statistics, probability and economics. The AI field draws upon computer science, information engineering, mathematics, psychology, linguistics, philosophy, and many others.

Examples – Amazon Alexa as an AI Product:

Amazon Alexa is a virtual assistant developed by Amazon, first used in the Amazon Echo and the Amazon Echo Dot smart speakers developed by Amazon Lab126. It is capable of voice interaction, music playback, making to-do lists, setting alarms, streaming podcasts, playing audiobooks, and providing weather, traffic, sports, and other real-time information, such as news. Alexa can also control several smart devices using itself as a home automation system. Users are able to extend the Alexa capabilities by installing "skills" (additional functionality developed by third-party vendors, in other settings more commonly called apps such as weather programs and audio features).

Predictive maintenance Template - Predictive maintenance encompasses a variety of topics, including but not limited to: failure prediction, failure diagnosis (root cause analysis), failure detection, failure type classification, and recommendation of mitigation or maintenance actions after failure. As part of the Azure Machine Learning offering, Microsoft provides a template that helps data scientists easily build and deploy a predictive maintenance solution.

Standard associated –
ISO/IEC JTC 1/SC 42- Artificial Intelligence

3D Printing

Information – 3D printing is any of various processes in which material is joined or solidified under computer control to create a three-dimensional object with material being added together (such as liquid molecules or powder grains being fused together). 3D printing is used in both rapid prototyping and additive manufacturing. Objects can be of almost any shape or geometry and typically are produced using digital model data from a 3D model or another electronic data source such as an Additive Manufacturing File (AMF) file (usually in sequential layers). There are many different technologies, like stereolithography (SLA) or fused deposit modeling (FDM). Thus, unlike material removed from a stock in the conventional machining process, 3D printing or Additive Manufacturing builds a three-dimensional object from a computer-aided design (CAD) model or AMF file, usually by successively adding material layer by layer.

Examples – This will fuel individualization and mass customization providing enhanced, customized products in different sects of personal life as well as industrial production, glasses, hip joints, aeroplane parts, car chassis etc.

Standard associated –
ISO/IEC JTC 1/SG 3 - 3D Printing and scanning
ISO/IEC JTC 1/WG 12 - 3D printing and scanning
CEN/TC 438 – Additive Manufacturing
ASTM - ASTM's Additive Manufacturing Technology standards are intended to promote knowledge of the industry, help stimulate research and encourage the implementation of technology. The standards define terminology, measure the performance of different production processes, ensure the quality of the end products, and specify procedures for the calibration of additive manufacturing machines.

AR/VR

Augmented reality (AR) is a technology that layers computer-generated enhancements atop an existing reality in order to make it more meaningful through the ability to interact with it. AR is developed into apps and used on mobile devices to blend digital components into the real world in such a way that they enhance one another, but can also be told apart easily.

AR technology is quickly coming into the mainstream. It is used to display score overlays on telecasted sports games and pop out 3D emails, photos or text messages on mobile devices. Leaders of the tech industry are also using AR to do amazing and revolutionary things with holograms and motion activated commands.

Virtual reality (VR) is an artificial, computer-generated simulation or recreation of a real life environment or situation. It immerses the user by making them feel like they are experiencing the simulated reality firsthand, primarily by stimulating their vision and hearing.

VR is typically achieved by wearing a headset like Facebook's Oculus equipped with the technology, and is used prominently in two different ways:

- To create and enhance an imaginary reality for gaming, entertainment, and play (Such as video and computer games, or 3D movies, head mounted display).
- To enhance training for real life environments by creating a simulation of reality where people can practice beforehand (Such as flight simulators for pilots).

Virtual reality is possible through a coding language known as VRML (Virtual Reality Modeling Language) which can be used to create a series of images, and specify what types of interactions are possible for them.

Standard associated –
Augmented Reality Framework: https://www.etsi.org/technologies-clusters/technologies/augmented-reality
Network Functions Virtualisation: https://www.etsi.org/technologies-clusters/technologies/nfv
5G: https://www.etsi.org/technologies-clusters/technologies/5g
IEEE P1589 - Standard for an Augmented Reality Learning Experience Model
IEEE P2048.1™ - Standard for Virtual Reality and Augmented Reality: Device Taxonomy and Definitions
IEEE P2048.2™ - Standard for Virtual Reality and Augmented Reality: Immersive Video Taxonomy and Quality Metrics
IEEE P2048.3™ - Standard for Virtual Reality and Augmented Reality: Immersive Video File and Stream Formats
IEEE P2048.4™ - Standard for Virtual Reality and Augmented Reality: Person Identity
IEEE P2048.5™ - Standard for Virtual Reality and Augmented Reality: Environment Safety

Robotics

Robotics is an interdisciplinary branch of engineering and science that includes mechanical engineering, electronics engineering, information engineering, computer science, and others. Robotics deals with the design, construction, operation, and use of robots, as well as computer systems for their control, sensory feedback, and information processing.

These technologies are used to develop machines that can substitute for humans and replicate human actions. Robots can be used in many situations and for lots of purposes, but today many are used in dangerous environments (including bomb detection and deactivation), manufacturing processes, or where humans cannot survive (e.g. in space). Robots can take on any form but some are made to resemble humans in appearance. This is said to help in the acceptance of a robot in certain replicative behaviours usually performed by people. Such robots attempt to replicate walking, lifting, speech, cognition, and basically anything a human can do. Many of today's robots are inspired by nature, contributing to the field of bio-inspired robotics.

Robotics is a branch of engineering that involves the conception, design, manufacture, and operation of robots. This field overlaps with electronics, computer science, artificial intelligence, mechatronics, nanotechnology and bioengineering.

Examples – Increase in robots has seen an impetus. It is further expected to grow rapidly in coming years. India will be one of the major forces to move towards robotics.
Humans & robots working together is the future. No need of robotic cells. Human robot collaborations is already a practice at many sites not only in the western world but also in India.

Standard associated –
ISO/TC 299
IEEE P7007
IEEE 1872-2015

Drones or Unmanned Aerial Vehicles (UAVs)

An unmanned aerial vehicle (UAV), commonly known as a drone is an aircraft without a human pilot aboard. UAVs are a component of an unmanned aircraft system (UAS); which include a UAV, a ground-based controller, and a system of communications between the two. The flight of UAVs may operate with various degrees of autonomy: either under remote control by a human operator or autonomously by onboard computers.

Compared to manned aircraft, UAVs were originally used for missions too "dull, dirty or dangerous" for humans. While they originated mostly in military applications, their use is rapidly expanding to commercial, scientific, recreational, agricultural, and other applications, such as policing, peacekeeping, and surveillance, product deliveries, aerial photography, agriculture, smuggling, and drone racing. Civilian UAVs now vastly outnumber military UAVs, with estimates of over a million sold by 2015, so they can be seen as an early commercial application of autonomous things, to be followed by the autonomous car and home robots.

Standard associated –
IEEE P2025.1
IEEE P2025.2
ISO/TC 20/SC 16 (Unmanned aircraft systems)

Edge Computing

Information – End-to-end solutions with high market potential, fully scalable hardware solutions, extensive data processing on the edge, and connectivity from the sensor to the cloud are a few benefits of Edge systems. The Industrial IoT presents new challenges for existing network architectures. The need to pre-process data acquired from machinery makes edge architectures the solution of choice. A holistic approach must also satisfy the demand for real-time communication and provide the necessary data processing functionality.
A key enabler of the digital industrial transformation is cloud computing. This relies on the Industrial IoT and makes edge computing an indispensable part of the overall concept. Edge computing is not an entirely new concept. It is an established method used to acquire, compress and aggregate large volumes of data as close as possible to its source using distributed devices – and then transform that data into actionable intelligence.

Examples – Providing intelligence at the edge at the factory level. The production sites can thus have complete control of data in their premise without moving to the cloud.

Standard associated –
ETSI Multi-access Edge Computing: https://www.etsi.org/technologies-clusters/technologies/multi-access-edge-computing

Cloud computing

Cloud computing is shared pools of configurable computer system resources and higher-level services that can be rapidly provisioned with minimal management effort, often over the Internet. Cloud computing relies on sharing of resources to achieve coherence and economies of scale, similar to a public utility.

Third-party clouds enable organizations to focus on their core businesses instead of expending resources on computer infrastructure and maintenance. Advocates note that cloud computing allows companies to avoid or minimize up-front IT infrastructure costs. Proponents also claim that cloud computing allows enterprises to get their applications up and running faster, with improved manageability and less maintenance, and that it enables IT teams to more rapidly adjust resources to meet fluctuating and unpredictable demand. Cloud providers typically use a "pay-as-you-go" model, which can lead to unexpected operating expenses if administrators are not familiarized with cloud-pricing models.

The availability of high-capacity networks, low-cost computers and storage devices as well as the widespread adoption of hardware virtualization, service-oriented architecture, and autonomic and utility computing has led to growth in cloud computing.

Standard associated –

CLOUD SECURITY ALLIANCE

The Cloud Security Alliance was formed to promote a series of best practices to provide security assurance in cloud computing. Its objectives include promoting understanding, researching best practices, launching awareness campaigns with the goal of creating a consensus on ways to ensure cloud security.

DISTRIBUTED MANAGEMENT TASK FORCE (DMTF)

The DMTF focuses on IaaS (Infrastructure as a Service), and providing standards that enable IaaS to be a flexible, scalable, high-performance infrastructure.

The DMTF is the group that developed the OVF standard that is formally known as DSP0243 Open Virtualization Format (OVF) V1.0.0. It describes an open, secure, and portable format for packaging and distribution of software that will be run in virtual machines.

NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)

NIST is a non-regulatory federal agency whose goal is to promote innovation and United States competitiveness by advancing standards, measurement science, and technology. They are focused on helping federal agencies understand cloud computing.

OPEN CLOUD CONSORTIUM (OCC)

The OCC goal is to support the development of standards for cloud computing and frameworks for interoperating between clouds. The OCC has a number of different working groups devoted to varying aspects of cloud computing.

OPEN GRID FORUM (OGF)

The OGF is an open community that focuses on driving the adoption and evolution of distributed computing. This includes everything from distributed high-performance computing resources to horizontally scaled transactional systems supporting SOA as well as the cloud.

THE OBJECT MANAGEMENT GROUP (OMG)

The OMG is an international group focused on developing enterprise integration standards for a wide range of industries including government, life sciences, and healthcare. The group provides modeling standards for software and other processes.

STORAGE NETWORKING INDUSTRY ASSOCIATION (SNIA)
The SNIA is focused on developing storage solution specifications and technologies, global standards, and storage education. This organization's mission is "to promote acceptance, deployment, and confidence in storage-related architectures, systems, services, and technologies, across IT and business communities".

CLOUD COMPUTING INTEROPERABILITY FORUM (CCIF)
Network Function Virtualisation (NFV) at ETSI
Founded in November 2012 by seven of the world's leading telecoms network operators ISG NFV became the home of the Industry Specification Group for NFV.Five years and over 100 publications later, the ISG NFV community has evolved through several phases, its publications have moved from pre-standardization studies to detailed specifications (see Release 2 and Release 3) and the early Proof of Concepts (PoCs) efforts have evolved and led to interoperability events (Plugtests). This large community (300+ companies including 38 of the world's major service providers) is still working intensely to develop the required standards for NFV as well as sharing their experiences of NFV implementation and testing.ISG NFV, like any other ETSI Industry Specification Group is open to ETSI members and non-members alike, with different conditions depending on ETSI membership status. If you would like to participate in this work, please contact the NFV support team. https://www.etsi.org/technologies-clusters/technologies/nfv

Cyber-security

Cyber security is the protection of internet-connected systems, including hardware, software and data, from cyber attacks. In a computing context, security comprises cyber security and physical security -- both are used by enterprises to protect against unauthorized access to data centers and other computerized systems. Information security, which is designed to maintain the confidentiality, integrity and availability of data, is a subset of cyber security.

Elements of cyber security
Ensuring cyber security requires the coordination of efforts throughout an information system, which includes:

- Application security
- Information security
- Network security
- Disaster recovery/business continuity planning
- Operational security

Examples –Security is a key element and is required end to end. The security in IIoT starts with Silicon, to the channel and is up-to the cloud. It starts with secure MCU, Secure channel in terms of TLS 1.2 and Security at the cloud/server.

Standard associated –
OWASP (Open Web Application Security Project)
ISO/IEC 27001 and 27002
ETSI Cyber Security: https://www.etsi.org/technologies-clusters/technologies/cyber-security
CEN CENELEC Cyber Security: https://www.cencenelec.eu/standards/Sectors/DefenceSecurityPrivacy/Security/Pages/Cybersecurity.aspx

NIST
ISO 15408
RFC 2196
ANSI/ISA 62443 (Formerly ISA-99)
WAVE (Wireless Access in Vehicular Environments)
IEEE 1609.2 WAVE Security

Role of Operational Technology in smart manufacturing

Convergence of IT and OT plays a vital role in making the smart manufacturing dream come true. Without a true vertical and horizontal connectivity, it would be impossible to build smart factories. Industrial IoT requires communication between the company level (enterprise) and the production level (MES/MCS). While IT is normally responsible for business data, customer data and intellectual property, OT is responsible for the entire manufacturing process.

Examples – Edge architectures for convergence of IT and OT.

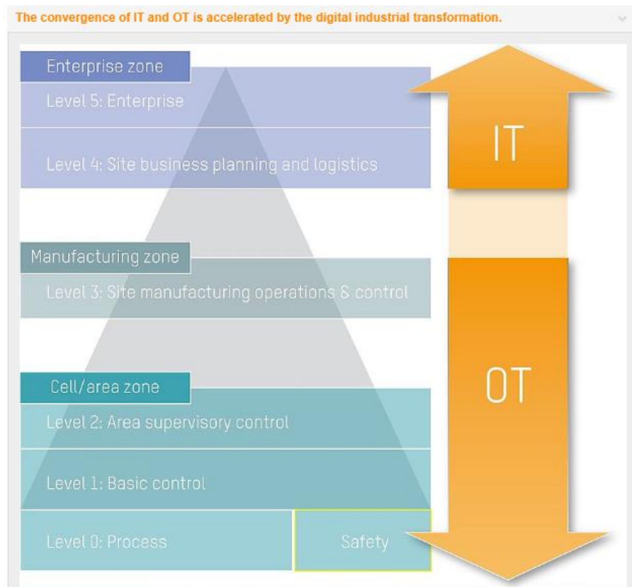

Figure 1: The Convergence of IT and OT

Smart Manufacturing Paradigm in India

The review of the trends and initiatives contextualized with the ground realities in the nation has given the following initial insights:

a. Research and development capabilities paired with engineering, software and technology integration abilities are essential ingredients for manufacturing enterprises. India is today viewed as a country with the capability to design, develop and manufacture innovative products for sale in local as well as global markets.
b. These factors explain, in part, India's rise from a low-cost, back office location to a country that is well positioned to be an active participant in the entire value chain and is now being

viewed as an integral part of the global manufacturing enterprise and location strategy of most of conglomerates with global footprints.

c. The recent Initiatives of the Government like Make In India, Skill India, Startup India, Smart Cities supported by enabling Policies & Regulations have truly energized the citizens, the corporates and global organizations to look at India as most conducive destination for setting up business and manufacturing. India being a big consumption market is an additional Bonus.
d. To make our industries a significant contributor to the manufacturing competitiveness, we need to build up a comprehensive indigenous ecosystem to cater to local as well as global needs. For this, we need to build a sustainable development mechanism and true technical competence in our engineers, design houses and EMS companies so that they meet the ever growing and changing needs and expectations of the global society.

To make it happen following are the challenges, which need to be addressed:

a. How can Industry **adapt and create** value?
b. Do we have the **skilled resources** to make it?
c. Is the present system **conducive for evolution**?
d. Is there a **coordinated approach** to address this?

Attempts have been made to analyze the situation in India and to get a snapshot of the current scenario regarding adoption of Smart Manufacturing in India. A caution must be sounded here that the scenario is mixed, as the manufacturing landscape in the country is a mix of very sophisticated large manufacturing units, as well as basic "tool room" type units of the SME segment – which constitutes a significant component of the manufacturing segment in the country.

Table 2: Primary Drivers fueling adoption of Smart Manufacturing process in India

Integration of Manufacturing Process with other systems like ERP/CRM	17.7%
Reduction of Wastage/Rejections	17.4%
Better utilization of manufacturing assets /better uptime	16.7%
Integration of Supplies into manufacturing process	14.9%
Integration of all shop floor assets into single network	14.5%
Efficiency improvement in IT driven manufacturing process	14.2%
Others	4.6%

As we can see, almost all the major drivers are related to integration of information flows between systems and enhancing the ability to integrate real-time information into a Decision Support System for manufacturing – thereby driving efficiency improvements.

Table 3: Leading inhibitors for adoption of Smart Manufacturing in India

Low people & process maturity	21.7%
Lack of technology standards	18%
Budgetary constraints	16.4%
Difficulties in tool/process integration	10.7%

Lack of IT resources & fear of missed upgrades	11.5%
Risks / Lack of top management support / no precedent	17.6%
Security Concerns	4.1%

Table 4: Potential components for Smart Manufacturing initiatives in India

Interconnected machines, assets etc.	21.9%
Mobile devices	16.1%
Analytics S/W	15.3%
Cloud computing (including migration)	12.4%
Big Data S/W	10.9%
On premises IoT Servers (Edge devices or Edge architectures)	8%

As we can see, these are "baby steps" being taken – to get different plant assets to start "talking" to each other. They are leveraging off existing assets (note the reference to cloud computing, big data and mobile device integration) – which points to Step Zero as the integration of existing (legacy) assets into the unified information network, so as to enable seamless flow of data. Note also the concerns with security and interoperability being voiced in the previous table

Manufacturing Process in India

Industrial assets are connected through different filed bus protocols such as CAN, Modbus, Profibus etc. The data is ingested form these machines using a PLC. The PLC provides relay control and input and output from the machine. It provides real time control of the machines from other systems in the plant through different filed protocols supported by the PLC.

Industrial communications are available traditionally on serial protocols. CAN is one of the popular serial protocol which is extremely popular in automotive world but is also used as a field bus protocol for Industrial control. Modbus is a serial communication protocol and is most commonly used to connect Industrial Electronic Devices.

Modbus Remote Monitoring and Control in India traditionally uses RS-485 and RS-232 transport for collecting data. Modbus RTU message transmitted with a TCP/IP wrapper and sent over a network instead of serial lines.

Many machines post 2005 have moved from serial buses to Ethernet based networks for machine level communication between PLC, motion, drives, sensors, I/O, safety etc. The popular networks widely used in India are Profinet, Ethernet I/P, POWERLINK and Sercos.

Today, many factories have a mix of legacy equipment, controls using fieldbuses and controls using Ethernet based networks.

Primarily machine-to-machine communication was established using Ethernet I/P, Profinet, Profibus, Devicenet, OPC DA (classic) or Modbus RTU or Modbus Ethernet.

Only large factories have some sort of networked architecture from the SCADA / DCS to the IT systems such as MES / ERP. Usually this was executed manually in most installation.

OPC Unified Architecture (OPC UA) is a machine-to-machine communication protocol for industrial automation developed by the OPC Foundation. OPC-UA is the successor to OPC-DA and is an open, vendor independent, royalty free protocol. This protocol can be implemented irrespective of the hardware and software. The challenge with factories in India is that the machines are old and do not support OPC-UA protocol inherently and there is a significant investment needed to upgrade the infrastructure to support OPC-UA.OPC UA is not a real-time protocol. Thus to further leverage the strength of this protocol, the OPC foundation is working on OPC UA TSN (Time sensitive networking), which will provide the determinism needed for machines and factories for transferring data. Today, Industrial Internet Consortium (IIC) has test-bed on TSN and we expect the commercial release of products for machines and factories in 2019.

DCU/SCADA -There are sectors where there is penetration of DCU and SCADA however, as seen the data is more local and used to monitor factory floor operations locally.

Current scenario of manufacturing Industry in India

This scenario has been captured from various aspects of our visits to customers and manufacturing units from different industry verticals. Also, it is very important for everyone to understand that Industry 4.0 is a need and not the end. It is essential for Indian companies to find out the right partner for having a successful implementation.

Automotive Industry

Automotive Industry in India is increasingly going digital, they are already highly automated, connected, and integrated. It is a journey rather than an absolute end state. Increased user demands of achieving high quality, accuracy and productivity are fueling demands for robots in India. Automotive industry is one of the largest consumers of robots with robots being deployed extensively in paint shops, weld shops, assembly lines and various other units. Conventional installation of robots bounds them by cages, safety doors, mats with a view to increase human safety. On the other hand, this approach reduces productivity, as opening these cages or interrupting the safety mechanisms usually cuts off the supply to the robots and brings them to a standstill. Re-starting robots post stoppages requires homing of the robot, which increases stoppages, waste and decreases productivity. With technology developments, robots no longer need to be bounded by cages, and it is possible for humans and robots to work together safely. With Industry 4.0, manufacturing units for such assembly lines need to actively deploy these approaches, helping them to increase productivity, ensure safe operations and reduce machine downtimes and footprint. This eventually gives rise to a lean manufacturing line with increased efficiency and safety. Today, Indian automotive manufacturers have initiated projects or at least thinking of moving to-wards Industry 4.0 readiness. Digitization is enriching every aspect of manufacturing and it is enhancing efficiency, accuracy, productivity and quality. It is increasingly observed that data driven decision-making is finding its way into manufacturing process. These new technologies are actual game changers and lead to higher profitability. It is clear that Industry 4.0 presents tremendous opportunities and this fact is highlighted by the industry demands for smart manufacturing. However, this industry is tech savvy industry and is already on the path for smart manufacturing in some form or the other.

Textile Industry

Textile industry is one of the healthiest segments in the Indian economy and contributes to the tune of 4% to our GDP. The Indian textile industry has two broad segments as unorganized sec-tor and organized sector. Unorganized sector consists of handloom, handicrafts and sericulture, which are operated on a small scale and through traditional tools and methods. The second is the organized sector consisting of spinning, apparel and garments segment which apply modern machinery and techniques such as economies of scale. Some of the major challenges that our textile industry faces today include organizational flaws in weaving and processing, a fragmented and scientifically backward textile processing sector, and infrastructural logjams in terms of power, road transport etc. Textile is more complex in operation, so to connect every machine for getting the real data without any manual intervention is a big challenge. Also, some of the machines are not automated and are still working with manual labor. There is immense low level of awareness about IT systems amongst users, which is another challenge. Everyone wants to focus on production, efficiency, etc, hence to train such a work-force is another big challenge. New technology adoption and digitalization can aim at improving production, productivity and quality of cotton resulting in better ROI.

Pharmaceuticals Industry

Pharmaceutical industry is amongst the top industries in India. Pharma companies have already begun switching to new technologies. The advancement of technology such as cloud computing, analytics, and the seamless access of Internet on various electronic devices have started trans-forming the healthcare industry in ways it was never imagined. Automation has been a key enabler in transforming the scenario. Due to globalization, more and more companies are becoming open to automation. Compliance with regulatory requirements, especially for export products, throws up new opportunities and challenges for automation suppliers. Laboratory processes are well suited for robotic automation as the processes are composed of repetitive movements and demand precision. Automation is also seeing growing usage in working environments which involve handling of hazardous compounds. With support from technologically advanced and innovative partners, Pharma industry can shift gears and further boost their efficiency and productivity throughout product life cycle. Apart from the laboratory, in production and packaging, Pharma companies are leveraging advanced technologies and automation. This addresses challenges such as sample under fill and over fills; detect foreign objects on the production line etc. These solutions help them address the above-mentioned issues on a running batch, thus reducing the downtime and help to follow the regulatory guidelines. Predictive analytics is the emerging technique for real-time management. Pharmaceutical companies are continually looking for new ways to better understand the upcoming trends. Applying big-data Strategies can better support decision-making with improved efficiency of clinical research and optimized innovation. Pharmaceutical companies are also investing in predictive analytical technique, which can help identify new potential drugs with a higher probability of being successfully developed and approved. From our point of view this is tech savvy industry and is already on the path for smart manufacturing.

Plastic Industry

Plastic industry in India is already well established. This is due to increased use of plastic products in industries and home appliances such as Automobiles, Packaging, Writing instruments, Household and Electrical accessories etc. In the plastics processing industry, the driving forces behind Industry 4.0 are the manufacturers of machinery. Some of the high-end plastic processing systems in India are equipped with an in-creasing amount of automation that is intended to enable them to communicate and process data to become smart. However, there is a cost issue in Plastics industry. The controls for plastic manufacturers are cheap and the cost of digitization is almost equivalent to his entire automation cost of one ma-chine. This is a major deterrent. Accelerated globalizations, rapid change in technology, and growing consumerism can bring about new changes and abundant opportunities the Indian plastics industry to grow locally and globally. But the Indian plastics processing and converting industry has large population of older technology machinery and thus does not have the same technological edge to remain competitive in costs and quality compared to our global competitors. To meet the challenges the industry is required to become competitive, cost effective and quality oriented.

Printing Industry

The Indian printing industry is increasingly being driven by growth in packaging and labels.
Driven by changes in technologies and with the onset of Industry 4.0, a profound digital transformation is underway within the printing industry. Printing industries are enhancing their capabilities with newer technologies and are investing in seamless workflows as a preliminary capability to drive innovation and make significant improvements in efficiency. Printing industry too has a mix of high end and low-end technology. Some are technology intensive where as some are cost sensitive. Thus, to have a total automated solution catering to demands of Industry 4.0 is a huge challenge. Embracing digital is a necessity in the current disruptive environment as it plays a pivotal role in enabling productivity, streamlining printing workflows, improve customer service and enable businesses in staying agile.

Metal Industry

Lack of modern technologies and weak infrastructural facilities leads to a process of metal making more time consuming and expensive. Such a situation forces India to import better quality metal from abroad. Thus, there is urgent need to improve the situation and take the country out of desperate position.
Also, CNC and machining verticals have dedicated controllers and to retrieve data from such machines is a major challenge for any one. Thus, due to unavailability of data there is no analytics. With the increased competition and demand in the global market, automation is becoming the necessity in Indian metal industry. Through the adoption of more efficient and advanced technologies, the increase in productivity in the manufacturing sector is effective in merging economic, environmental, and social development objectives. Indian steel industry over a period has modernized; this has played a vital role for competing in global market. The main advantage the Indian Steel industry is having the availability of domestic raw material and low labor cost. However, there is a complete paradigm shift in the thinking needed for Industry 4.0. Implementation of smart manufacturing practices will lead to smart utilization of technologies, cut down wasteful expenditure, proper utilization of processes and manpower. Metal Industry would be benefited a lot if they adopt the new technologies. This would also lead to reduction in accidents at workplace.

Typical Architecture of Manufacturing Processes in India

The below architecture is currently being explored by factories for having a seamless data connectivity with gateway mechanisms. Only the left 3 boxes are currently available in the form of an automation pyramid. The automation pyramid on any shop floor is also shown below.

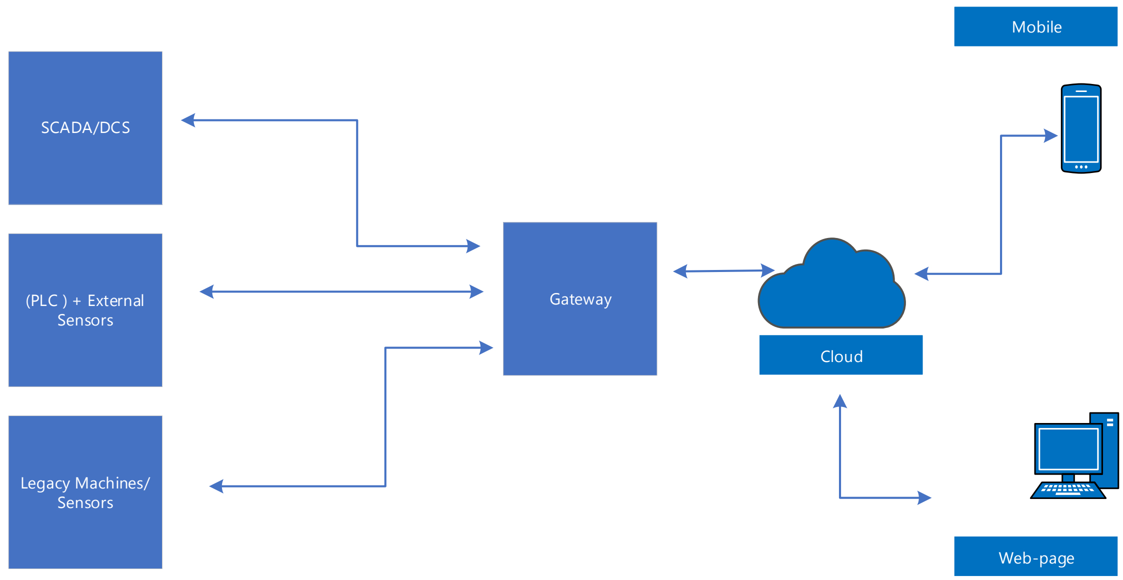

Figure 2: An ecosystems, which is expected while integrating all elements in a manufacturing setup. The Factories need to connect right from sensors, actuators, controllers to the IT and to the cloud.

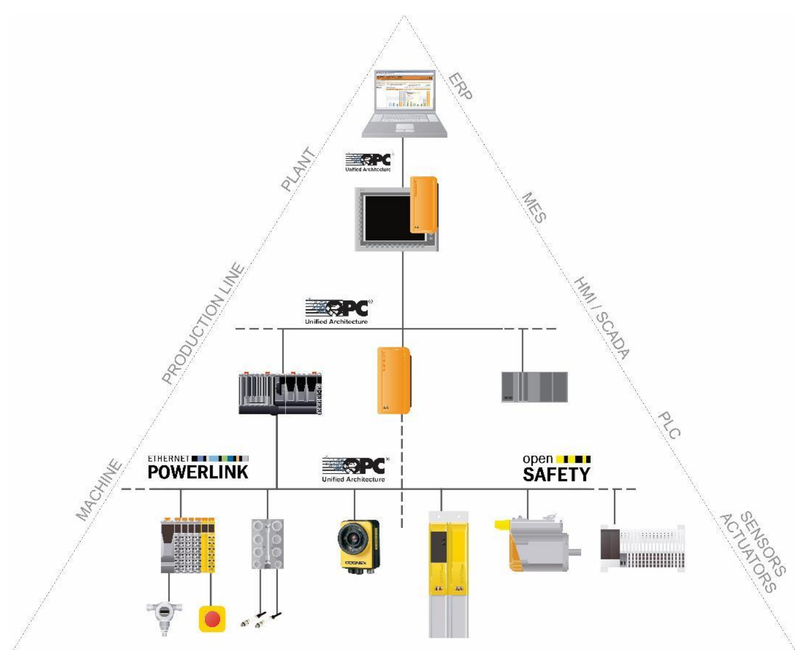

Figure 3: A typical Automation Pyramid in a manufacturing setup segregating into main categories - Machine level, Factory level, Plant level & IT infrastructure

Challenges with Manufacturing Processes

The biggest challenge today with factory in an emerging country like India is the machines are old, sometimes with legacy PLC and at times without PLC. There are also instances where the machines are closed by OEMs and all communication ports are blocked.

Security - If you look at a typical manufacturing factory floor, there are few assets which are there in remote locations which are usually unattended, managed remotely and have extremely low resources and are on network. Hence, they are quite venerable and have elevated risk of security attacks. Many MSMEs worry about data security and the misuse of data, in case their production information leaks outside due to cyber-attack.

Machine lacks Sensors – Most of the legacy machines were designed and never thought that they would get connected at some point of time and hence lacks sensors and any other median to get connected.
Ownership of adopting advanced technologies go with the top management usually in MSMEs. If the top management is not willing to trust these next generation technologies, there is a slowdown in approach. In addition, the risk of failure is a deterrent in adoptions.

- Lack of a common protocol connecting field devices and shop floor.
- Level of investment needed vs the RoI.
- Workforce skilling and training
- Awareness of availability of new technologies in India. There are many cost-effective open source technologies available. But due to lack of awareness the rate of adoptions is slow.
- Lack of greenfield projects.

Workforce re-skilling – A different kind of a challenge
With IIoT, users face new challenges related to security, maintenance, shop-floor connectivity and many more. The lack of adequate skills and education acts as a major deterrent to adopt new technologies. Workplace education programs can help current employees of manufacturers gain knowledge and equip them for technology changes. On the other hand, for manufacturers, labor and productivity is equally important. Considering the current trends and future challenges, few manufacturers have already started investing in training and skill development centers. These centers allow their employees to try complex concepts in industrial processes. However, the gap between adoptions of fast evolving technologies and skilling is huge and is continuously expanding. When manufacturers or automation vendors talks about implementing IIoT, the discussions is always focused on technologies, electronics, hardware, software, sensors, network connectivity and many more. For handling and implementation of new technologies, skill is also a necessary aspect. Along with the solutions and technologies, there has to be a strong focus on specific industry trainings where workforce obtains skills to evaluate information and technologies effectively enabling them to keep pace with current industry trends.

Use cases

Remote Monitoring

In order to get visibility of the machines in a factory floor, it is important to know the real-time status of the machines. This is important in order to reduce the downtime and keep operations smooth and increase overall productivity. Remote monitoring is the first step in the IIoT journey to get visibility into the assets of the factory floor. The critical parameters which are captured from the factory assets are used to calculate OEE (Overall Equipment Efficiency). This factor gives a visibility into the inefficiencies in the manufacturing system and by getting these insights, how the system can be made more efficient. It is most essential for diagnosing and maintaining machinery and equipment. This solution should utilize the latest IT and security standards and should allow for significant savings with low investment costs. Like consumer goods, machines and systems are now sold in all corners of the world. Modern communication and transportation bring distant locations ever closer together. Modern production and logistics systems enable markets on a global scale. However, for machine builders, having customers around the world also comes with its share of new challenges. The situation becomes more difficult when it comes time for more extensive maintenance. To avoid the cost of flying service technicians and engineers halfway around the world, machine builders have to increasingly rely on remote maintenance and diagnostics. This solution reduces the machine downtime, plus reduces the overheads in maintenance, increases productivity.

Predictive Maintenance

Predictive Analytics are important for predicting ahead of time, the failure of the machines based on real time data fed to trained models. The models are trained using Machine Learning data gathered over a period of 12-14 months whereby the models are able to predict the failures with fine accuracy. This aids in reducing the unplanned downtime of the machines.

Collaborative Robots

Human robot collaboration is another avenue. Humans and robots working hand in hand is no longer a dream but a reality. The advancements in Robotics technology, miniaturization of electronic components and processors along with Industrial IoT has given birth to Collaborative Robots (or Cobots). Collaborative robotics combines the skills of both humans (problem solving, flexibility etc.) and robots (precision, strength etc.)

This will definitely increase productivity, reduce downtimes and at the same time make the shop floor friendlier to humans.

Energy-efficient Factory Floor

Saving energy and increasing productivity are not mutually exclusive. The much-anticipated ISO 50001 international standard “Energy management systems – Requirements with guidance for use” was published in 2011. According to estimates, up to 60 percent of the world’s energy use could be positively influenced by this standard. With forecasts predicting at least a 20 percent increase in energy prices by 2020, improving energy efficiency will be an effective way to control costs in addition to securing a competitive edge. Some terminology in this standard has been changed compared to EN 16001, with the introduction

of an additional component – “Management responsibility” – which calls for a stronger role for administrative personnel. Nevertheless, the transition to ISO 50001 is generally considered a step forward for most organizations.

Energy consumption by area
When looking at the amount of energy consumed for buildings, industry and transport, it becomes evident that approximately 70 percent of energy is used for industry and buildings.

Total energy consumption
Total energy needs are covered primarily by oil, gas and electricity. Electrical power, heating and water are used intensively in buildings. In industry, energy sources are highly dependent on the sector.

Various sources of monitoring
Gas, Oil, Steam, Thermal, Air, Water & Other, including renewable energy sources

End to End Visibility

A mere usage of Technologies like RFID and usages of sensors enables both Process and Product/Assets visibility from raw material to final product.
With increased asset (products or tools) visibility people don't have to search for products or tools thereby saving lot of time and improves the cycle-time.
Increased process visibility through sensors and feedback from robotic elements enables the manufactures to increase the throughput, reduce WIP inventory, Gain detailed insight by correlating operational data with real-time process interactions, Enable more flexible manufacturing practices by uncoupling processes from fixed work zones.

Operator Enablement

Spreading awareness and enabling operators with skills. This topic is covered as a separate topic in this pre-study standardization report.

Recommendation & Conclusions

Security is the biggest challenge in most of the connected assets today. The way assets are getting connected, they do not follow the basic essential security measures for securing devices, securing channel. If the IoT solution provider is using open source data ingestion services, then it is very important to have adequate security on the hosted server/cloud. The major cloud providers who provide IoT services do have adequate security measures on the cloud. The following are the recommendations for devices, channel and cloud.

Devices

IoT devices have constrained in terms of storage, memory, and processing. Since the footprint is less, the encryption and decryption also take long time. Many of the IoT Platform vendors do not have a secure and robust mechanism for authentication and provision for remote devices. The solution to this is to use a security coprocessor either on-chip or interfaced to with a processor to platform module to provide security of Keys. It is recommended to use certificate-based authentication to prove their identity. The devices should be capable to have firmware update over the air. It is equally important to have channel security where recommendation is to use standards like TLS 1.2.

Edge

Edge plays a vital role in Industrial IoT. This has been the forte of Embedded Systems (ES) where there are specific vendors who have boards qualified to be used on Industrial factory floor. Intelligent Edge is imperative for applications where Edge should be capable to have bare minimum workflow to keep the critical alarms and at times local display showing critical data on floor, connected to edge functional in event of connectivity loss. With edge getting stronger in terms of processing power and memory resources, there is a lot of scope for creating Machine Learning (ML) algorithms-based models which can provide the required intelligence at the edge.

Communication Standards

There are various filed bus protocols which you find in assets for factory floor like CAN, Modbus, Profibus. There are new standards which are emerging like OPC-UA. Industry 4.0 puts OPC-UA in the forefront of Industrial connectivity. The biggest advantage OPC-UA brings to focus is interoperability. All the assets which are on the factory floor can be connected to each other using OPC-UA in a client-server mode and make interoperability seamless. The recommendation is to explore OPC-UA as medium for communication between assets in a factory floor. With TSN, OPC UA will not only provide client / server models but also Pub / Sub models guaranteeing the data delivery times.

Non-standardized interfaces: Hindrance in connectivity - Achieving horizontal and vertical integration/connectivity is necessary for a successful IIoT and Industry 4.0 implementation. Horizontal or vertical connectivity and integration in a factory or plant can only be achieved if all the vendors conform to common standards for communication. It implies that all the vendors should use a common language of communication. But the current market scenario today is very different and there are many proprietary communication technologies being used and promoted which prove as a hindrance for complete plant connectivity. This leads to high cost for development and maintenance of multiple, congruent solutions. Eventually the plant and factory operator and builder need to coordinate with multiple vendors resulting in excessive hardware costs and implementation delays.

Open connectivity from field to cloud - Based on the needs of the user there could be different variants of Ethernet which are open source at the same time based on standard Ethernet and complying with the IEEE 802.3 which can be deployed in the factories and plants. The process layer, MES and ERP needs Ethernet based communication which is not real time but offers a high level of security. The network which is active at this layer should have appropriate connectivity options to the cloud without having the need for hardware modifications. Similarly, the network in the field connecting the sensors, actuators, motions components and other field devices needs to be real time and deterministic. As the need is for an end to end connectivity the network too has to be based on standard Ethernet. Safety is a crucial aspect in Industry 4.0 and to have a safe horizontal and vertical communication all vendors' needs to comply with safety, which is able to exchange information on these different Ethernet based buses. *OPC UA: Process to cloud or MES / ERP* - Using available open source solutions is the answer to the current market situation and breaking the shackles of proprietary solutions. This is also a crux of the Industry 4.0 approach. OPC Unified Architecture (OPC UA) which is handled by the OPC Foundation is a completely open source, vendor and platform independent solution based on standard Ethernet. Its simplicity is enhanced by the use of PLCopen function blocks for programming. This provides a non-real time communication from the various machines to the upper layers as well as facilitates a machine to machine communication without hassles using the existing systems and controllers. OPC UA also offers connectivity not only till ERP

/ MES but also upto the cloud as many cloud providers already have OPC UA drivers readily available for usage. OPC UA has robust security mechanism already in place to meet the IIoT needs and Industry 4.0 needs of the plants and factories.

Conclusion

The Smart Manufacturing imperatives in India are beyond the global imperatives; hence India is looking at Smart Manufacturing as an inclusive strategy (beyond simply leveraging the ICT) to empower the Indian Manufacturing Ecosystem to catapult Indian Economy on a comprehensive growth trajectory.

The standardization initiatives in this domain shall strive to look at enabling Indian companies to leverage the power of ICT technology to improve profitability and achieve sustainable growth. The goal is not to blindly follow western models, which focus exclusively on automation to achieve these goals, but to evolve “India-appropriate” models, which address the unique challenges of the Indian environment. India cannot afford to consider Smart Manufacturing as a separate domain, rather as a homogenous sub-domain in the comprehensive & complex domain of Smart Infrastructure.

Hence, India needs a homogenous & harmonized set of standards, architectures and frameworks amongst all individual domains like Smart Homes, Smart Buildings, Smart Grids, Smart Manufacturing, Smart Cities being the complementing components of the uber complex paradigm of Smart Infrastructure.

It is envisaged that common, unified and harmonized Standards shall bring the cost of all products, systems and solutions with multi-domain applications down comprehensively, avoid the market fragmentation & segmentation, and multiply the volume of manufacturing of the respective products and systems hence boosting the Manufacturing Ecosystem.

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Annexure

The table below summarizes standards published by CEN/CENELEC/DIN relevant for smart manufacturing:

List of Standards relevant for Smart Manufacturing	
Document No.	**Title**
EN ISO 6385	Ergonomic principles in the design of work systems
EN ISO 9001	Quality management systems -- Requirements
EN 16710-2	Ergonomics methods - Part 2: A methodology for work analysis to support design
EN 614-2	Safety of machinery - Ergonomic design principles - Part 2: Interactions between the design of machinery and work tasks
EN ISO 10218	Robots and robotic devices - Safety requirements for industrial robots
EN 894-1	Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 1: General principles for human interactions with displays and control actuators
EN ISO 12464	Light and lighting - Lighting of work places
EN ISO 9241-960	Ergonomics of human-system interaction - Part 960: Framework and guidance for gesture interactions (ISO 9241-960:2017)
EN ISO 9241-125	Ergonomics of human-system interaction - Part 125: Guidance on visual presentation of information (ISO/DIS 9241-125:2016)
EN 1005-1-5	Safety of machinery - Human physical performance -Part 1-5
EN 614-1-2	Safety of machinery - Ergonomic design principles - Part 1-2
EN 894-1-4	Safety of machinery - Ergonomics requirements for the design of displays and control actuators - Part 1- 4
EN ISO 12100	Safety of machinery - General principles for design - Risk assessment and risk reduction
EN ISO 13857	Safety of machinery - Safety distances to prevent hazard zones being reached by upper and lower limbs
EN 13861	Safety of machinery - Guidance for the application of ergonomics standards in the design of machinery
EN ISO 26800	Ergonomics - General approach, principles and concepts
EN ISO 14738	Safety of machinery - Anthropometric requirements for the design of workstations at machinery

EN 349	Safety of machinery - Minimum gaps to avoid crushing of parts of the human body
EN 547-1	Safety of machinery - Human body measurements - Part 1: Principles for determining the dimensions required for openings for whole body access into machinery
EN ISO 15265	Ergonomics of the thermal environment - Risk assessment strategy for the prevention of stress or discomfort in thermal working conditions
EN ISO 7730	Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
DIN ISO 45001	Occupational health and safety management systems - Requirements with guidance for use
DIN ISO/TS 15066	Robots and robotic devices - Collaborative robots
DIN CWA 16649	Managing emerging technology-related risks

These standards should make it easier for companies to connect their existing and new equipment, regardless of their service provider. Therefore, the publication of European standards is expected to drive the further rollout of Industry 4.0 in the coming years. Although such standards are voluntary, you should comply because they allow you to sell your products across Europe.

मानकः पथप्रदर्शकः

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