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Research Article

Adoption Of Digital Technologies In The Manufacturing Sector

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ABSTRACT

Introduction: Manufacturing is important to a nation and its economy, and digitization of manufacturing will enhance the productivity and create new types of jobs. This sector is a big source of innovation and opportunities in the growing "clean economy." However, the biggest challenge in digital manufacturing is to break the established roles and processes of the organization.

Method: The research approach is to identify the parameters, capabilities/skills and business values to measure ecosystems for IT investment in the manufacturing sector and identify mechanisms for pilot projects for scaling up and the challenges in adoption of digital technologies.

Results: The article tries to find out the capabilities, skills and mind sets which is needed in the organization for digital manufacturing and challenges for digital adoption using content- centric literature review on digital manufacturing.

Conclusion: Advanced manufacturing practices drives significant impact for the global footprints and portfolios. Digital systems will transform the design, manufacture and operation of the products and production systems.

Keywords: *digital manufacturing; manufacturing industry; digitization values; digital adoption*

1.0 Introduction

The landscape of digital technologies is wide and varied. There is a wide spectrum of technologies which are classified as digital technologies - internet of things, mobile technology, cloud computing, social media, analytics, big data, in memory computing, virtual reality, 3-D printing, 5G Mobile telephony etc. There are rapid advancements in each of these technologies and newer technologies are emerging as well, making the landscape wider, with exciting changes and increasingly complex to navigate. This ever-changing, complex to navigate landscape of digital technologies while offering immense opportunities to transform businesses, being an unchartered territory does pose challenges of adoption.

The growth and productivity enhancements of the manufacturing industry are critical to economic advancements of any country/economy. IBEF Reports (2024) indicates that manufacturing industry in India generated 16-17% of country's GDP and is projected to be one of the fastest growing sectors of the economy. The report indicates that with digitization India can become a global manufacturing hub. It is expected that digital connectivity will unlock various value and transform the manufacturing landscape forever.

The different digital technology elements either individually or in combination with other digital technology elements is expected to make significant impact on manufacturing sector. With its investments in manufacturing processes, tooling, operational elements etc. being difficult to modify investments, manufacturing would require imaginative thinking and careful planning to adopt digital technology. This article intends to explore and formulate frameworks to adopt digital technology by the manufacturing sector.

2.0 The Imagination and use cases

Whenever new technologies emerge, it is observed that immediate areas of adoption are not very obvious. This phenomenon is described by the S curve and by the Gartner's hype cycle. Given these characteristics of adoption, many times it is the human imagination which drives growth and adoption of new technology. However when there are limits to understand areas or models of adoption, the trigger to human imagination could come not from precedents but by imagining the scenarios using other fields of human pursuit. The grand

sweep of imagination to visualise the possibilities of digital technologies comes from the philosophical underpinning of evolutionary biology. (Dennett and Roy ,2015)

The great narrative that emergence of digital technologies are equivalent to emergence of light sensing (eyes) organs in animals and the possibilities are limitless as similar to the explosion of animal forms post emergence of light as a means of sensing the external world in the animals.

The living organisms for a long time in the history of life were dependent on pressure, temperature, chemical properties etc. to sense and react to the eternal world. Proximity or near proximity was critical to sense the outside world for these animal forms. Geologist Andrew Parker developed hypothesis on the biological revolution called Cambrian explosion which occurred in the sea, a few billion years ago. There was a change in the chemistry of the shallow oceans and atmosphere, which resulted in evolution of eye, the ability to sense light by the animal world. This ability to sense the world from a distance through light instead of only the proximate means like pressure, lead to explosion of life forms, the structures, the means of sourcing food, the mechanisms for protection and attack etc. (Dennett and Roy ,2015)

Philosophically, this seemingly unconnected phenomena of evolution eye and the associated Cambrian explosion of life forms on earth, provides a broad sweep of imagination to understand what could be the impact of digital technology on human organisations – government, business, social structures, military, trade, etc. While the imagination on the broader impact is unbound, the specific possibilities are numerous and have to be formulated with rigorous details, experimented to understand limitations, challenges and scaled up through incorporations of careful observations. Some of the possible triggers for imaginative thinking could be

- The structures: As the "Light switch theory" by Parker (Parker, 2003), indicates organizations need to change their sense to handle external interfaces and internal relations.
- Transparency: Many organisational philosophers opine that transparency is like sunlight, having the greatest disseminating and disinfecting qualities. When Digital technologies bring in added transparency, organisations would require mechanisms for handling transparency as well as processes protect the information, product details etc.
- The mechanisms of defence: Digital technologies increase the need for formulating effective defence mechanisms. In order for the organizations to survive in the evolving transparent world, organization needs to invest continuously in encryption and decryption schemes
- The strategy for the digital future: The ever evolving social world may result in a massive diversification of organizations with different focuses. Organizations may look into social purpose or profit. It would depend on the competitive priority which the organization wants to focus for their survival.
- Evolving ecosystem: Along with change in the organizational culture, a different type of ecosystem is needed for every sector, in terms of what is treated as an asset, the mechanisms for interfacing with the outside world, how innovations are fostered and adopted etc.

While the possibilities for innovation and adoption of digital technologies are numerous, a few use cases indicate how digital technology could be innovatively adopted by manufacturing organisations.

- **Plant Maintenance:** Areas where digital technologies can be adopted are for finding the failure characteristics of major equipment model, condition monitoring of equipment, predictive maintenance, Process controls.
- **Quality management and Regularity compliance**: Application of digital technologies in Pharmaceutical industry in areas like continuous monitoring conditions with mixing vessels, lyophizers, tablet presses, detect counterfeit medicine and containments, etc for quality control and regulatory compliance
- **Operations of Consumer goods industry**: Digital technologies enable faster to customer preferences, reduce supply chain costs, Faster update on latest inventory count which will result in providing building good bonds with customers
- **Managing complexities of Aerospace and defence industry-** This industry has enormously complex supply networks. The complex nature of design makes a huge impact in the manufacturing of many other components, which will impact the cost, quality, delivery.

The digital technologies for manufacturing: There are many digital technologies which have specific application in manufacturing industry. There are many use cases of these specific technologies.

- Manufacturing processes: Some of the key technologies are - fabricating novel materials, sensors to detect defects and robotics to improve productivity. The 3D printing has enabled producing jet engines which can reduce time, cost and materials needed in production (GE Look Ahead, 2013).
- Digital manufacturing: Technologies like automation, robotics, additive manufacturing, human-machine interaction are transforming the manufacturing value chain from research and development, supply chain and factory operations to marketing, sales and services.
- Advanced analytics: Application of analytical tools in near real-time situations have potential for transforming process control, quality management as well optimising plant operations and supply chain. A Japan based Consumer Packaged Goods company has leveraged detailed stock keeping unit level cost data

from each of the factories and developed an analytical tool to find out where and when to ramp up the production (McKinsey , September 2021).

3.0 The Research Methodology

While it is important being imaginative while visualising the application of digital technologies, it requires a systematic assessment and planning to incorporate the possibilities offered by digital technologies in the business transformation efforts. This paper investigates some critical areas to be addressed in the journey of business transformation and develops a framework for systematic planning and execution. The areas are:

- Assessment of the ecosystem and landscape of digital technology: What are the emerging technologies, how each of these could impact or disrupt the industry
- Assessment of the value: Where is the value for my company?
- Formulation of capabilities: What new capabilities, skills, and mind-sets will we need in our organization?
- Plans for adoption: How should be the pilot project for digital technology, how to assess the pilot project and how to plan for scale up to capture business value?

The research work complements previously published studies in the manufacturing domain. The research approach is to identify the parameters, capabilities/skills and business values to measure ecosystems for IT investment in the manufacturing sector and identify mechanisms for pilot projects for scaling up and the challenges in adoption of digital technologies.

4.0 The findings and discussion

The research findings attempt to answer each of the above-mentioned questions with specific examples and use cases.

4.1 Ecosystems for the manufacturing factory of the Future

Digital technologies have changed the way in which companies position themselves. Digitally connected cars are causing traditional manufacturers to reposition as mobility and technology service providers. Given the increasing complexity of operations, technologies such as lean tools and Industry 4.0 tools are widely used in manufacturing sector. Lean management by itself is not sufficient to address the operational challenges.
Manufacturing is a data rich industry, making it one of the ideal candidates for using AI. AI powered robots can work autonomously or cooperatively with humans to enhance the capacity. New advances in data processing, real-time analytics have prompted innovative IoT applications that provide insights when and where they need most. IoT and AI meet to drive increased availability, quality, and performance. Research throws up some interesting trends as indicated in these use cases.

- Condition -Based Monitoring: Sensors along with IoT devices can provide meaningful insights into the current health of various devices or items of equipment in buildings. Sensors combined with microcontrollers along with security solutions can enable predictive maintenance.
- Analytical view of historical/run time data: These systems will use analytics along with big data and industrial internet of things to have the analytical view of the manufacturing. Manufacturing analytics software like Mingo helps to solve problems at the initial stage.
- Alerts on predicted issues: These systems need to alert on defective part, production delays, upcoming critical calibration events , notifies finance teams about open order backlogs, excessive labor ticket costs, etc.
- Generating maintenance recommendations: Future manufacturing systems can use IoT to monitor and predict with the least human interferences. (Velmurugan, 2022) Smart maintenance practices , technologies such as Artificial Neural Network(ANN), Artificial Intelligence(AI), Internet Communication Technology (ICT) and machine learning maximize the possibility of maintenance recommendations
- Quality Management Systems(QMS): Robust quality management software is needed to support continuous improvement and other regulatory standards. For example, Intellect QMS software features access controls/ Permissions, Compliance management, Version Control, Quality Control, Corrective and Preventive Action (CAPA).
- Worker Safety systems: Future manufacturing organizations invest in software to streamline health and safety monitoring procedure. These systems will be integrated with safety documentations, dynamic health and safety in-app training, available as web-based and mobile app.
- Autonomous operations: Autonomous IT systems rely on machine learning and predictive analytics to correct future issues, or to respond to issues in real-time.

4.2 Investment for the future manufacturing sector

There are digital technologies which have the ability to process the historical data, integrate the data and visualize the data. It is expected that these technologies can be the drivers of good manufacturing practices in the future. Some of the technologies and the uses cases are:

Video analytics: Some of the applications of video analytics include integration of historical data with data streaming from the edge to gain a complete picture of their operations. AI algorithms leverage the information to label images and subjects and become increasingly effective at recognizing when specific events occur. These applications are used for predictive maintenance, quality management, worker safety and autonomous operations.

Predictive and Prescriptive maintenance: The ability to process data where it is created allows system to recognize patterns of anomalies instantly. These applications can be used to predict potential maintenance issues in real time, and alert manufacturers in real time. This has resulted to resolve problems without the need for human intervention. These capabilities have resulted in decreased uptime, higher productivity and Safety for people.AI can analyse the impact of failure and the cost of proactive fix. Manufacturers can then link the prediction to one of the following: Generating a maintenance ticket, shutting down the equipment, calling the vendor for the needed replacement.

Quality Assurance: AI/ML algorithms provide an extreme level of accuracy when identifying defects in products. With this methodology, the entire task of quality inspection can be automated at the edge, and the fault detection can be accomplished instantly.

4.3 Values of digitization

The survey of manufacturing executives on Steering IT into the digital manufacturing era, indicates (2014) that digitization could drive significant impact through the following ways:

Enhancing Productivity: Mobile devices in the system can give real-time information on equipment performance. The greater transparency afforded by big data adds to the effectiveness of lean tools and promotes continuous improvement.

Speed: A control tower gathers data such as production order, capacity utilization, inventories, etc. from various sources in an integrated value chain, an algorithm generates each day's ideal production plan. With the output, the company can select plans in real time, using criteria such as efficiency, lead time and customer priority. Automatic replenishment of parts can be done with its help

Quality: Supplier can be given a self-inspection process, workers to perform visual quality checks of their outputs.

Safety: Fit operators with sensors that will alert them to the presence of dangerous gases or the possibility of clash with nearby forklifts or trucks.

Quantifying the Improvement Potential: Companies that use integrated lean industry 4.0 approach, can reduce conversion costs by as much as 40%.

Enhancing resilience: Managing resilience has become a top priority. In the survey conducted by McKinsey (McKinsey Report, 2021) indicated that 93% of supply-chain leaders identified the need to increase resilience. If the company starts deploying robots before processes have been optimised, the robots will perform non-value-adding activities- that reduces the deployment's financial return.

4.4 New capabilities/ skills, and mind-sets will we need in our organization

The survey of manufacturing executives on Steering IT into the digital manufacturing era, indicates (2014) the following developments:

- With the digital invasion in manufacturing, it is possible to make things economically, more flexible, with a much lower input of labor, with lesser raw materials and new collaborative manufacturing processes. This results in manufacturing locally, whatever product each market requires.
- As manufacturing goes digital, some of the business of making things will return to developed countries. One of the major applications that affected the digital manufacturing is 3 D Printing. This technology does not need the economy of scale for manufacturing. The cost of setting up machine is the same whether it makes one thing or as many things as can fit inside the machine. This technology is widely used to make specialist parts of a car.

- New collaborative manufacturing services are available online. Communities offering 3D Printing and other production services are already forming online- a new phenomenon which might be called social manufacturing.
- Arrays of manufacturing technologies which are emerging, making the manufacturing sector processes jobs-light. But some assembling components operations remain too fidelity for robots to do well, such jobs may be transferred to low-wage countries.
- Materials used to make things are changing as carbon-fibre composites will be replacing steel and aluminium products. There will be millions of small and medium sized firms that will benefit from new materials, cheaper materials, cheaper robots, smarter software, an abundance of online software and 3-D printers than can economically print in smaller numbers
- Manpower training needs to be done differently. Training can be done by collaboration between community colleges and local firms. Trainers can simulate production lines With new ideas, factories of future needs to look into how these ideas can be converted to products by training in universities and research laboratories.
- Next generation Robots are cheaper and easier to set up. They will work with people rather than replacing them. They will fetch and carry parts, hold things, pick up tools, sort items, clean up and make themselves useful in myriad other ways. Various efforts are underway to produce such robots, especially for smaller companies, These robots must be safe enough to operate alongside workers and capable of understanding simple instructions, including voice commands.

4.5 Steps to capture value by digitization

In the pilot production line, a joint venture between MIT and Novartis, an attempt has made to produce a copy of the standard Novartis drug. It relies on a combination of chemistry and engineering processes to speed up some processes and slowing down others to make them work together. Continuous manufacturing enables to manufacture in a small regionalised plant. Such plants will benefit by

Innovation: Access to model factories and mobile labs where managers and executive can try out new technologies and gain insights into the new opportunities. Participating in hands on simulations can help to improve performance.

Pilot: Develop a minimum viable solution and improve it using iterations using agile development methods. At the same time, company should deploy all the relevant enablers to get the success.

Scale: The company should conduct the rollout in a logical sequence, that allows for integrating solutions effectively when deployed at full scale.

4.6 Quantifying the impact of Advanced Manufacturing

To provide quantitative understanding of the impact, a study made in German based manufacturing industry (BCG Report, 2015) indicated the following:

Productivity: Productivity improvements will vary by industry. Industrial component manufacturers such as machinery manufacturers may achieve some of the biggest productivity improvements. (20 percent to 30 percent), automotive companies can expect increases of 10 to 20 percent.

Revenue growth: Enhanced equipment and new data applications by manufacturers and a variety of customer products will drive an additional revenue growth of $30 billion per year.

Employment: During the next ten years, there will be an increase in 6% employment. This requires a skill in robotic process automation, connectivity, and analytics. Employment will increase in software development, IT technologies, such as mechatronics.

Investment: Adapting production processes to incorporate industry 4.0 for manufacturing globally, requires an approximate investment of €250 billion.

5.0 Challenges

Mattias Ulbrich (2016) in the report on digital manufacturing mentions the challenges encountered when adopting these new generation technologies

Resistance to Change: People with different roles will be in different parts of the organization and in different parts of the world tended their own of doing things. Hence everyone needs to be motivated to adopt to change. By establishing permanent dialogue between business and IT, key transformation agents can enable changes in the organization. For example, digital tracking of vehicles in an automakers organization, meant training thousands of employees on products, process, quality and logistics in the new way of working.

Involvement of Senior leadership Team: The senior management team must devote time to the change process.

Change in the organizational Structure: Classical hierarchical structure may not be the ideal for the information flow. Cross-functional teams and interdisciplinary collaboration will add value to the organization.

Develop deep Technology Expertise: Outside traditional areas of IT, investments in robotics process automation, machine learning and augmented reality are needed.

Conclusion

Advanced manufacturing practices drives significant impact for the global footprints and portfolios. Digital systems will transform the design, manufacture and operation of the products and production systems. Connectivity and interaction among parts, sophisticated machines make the productive systems much faster and elevate production to new levels.

Significance of the research

The digital marketplaces are actively providing advantage to small players, suppliers, designers, managers, workers, and the entire manufacturing ecosystems. To harness the benefits, every player needs to understand IT systems, IT skills/capabilities and benefits of the digital manufacturing. In the present marketplaces where profit margins are thin and consumers demand are more sophisticated, there is a huge benefit to organizations by understanding the IT ecosystems of the future. These advantages and the wealth they create will become the basis for greater world-wide prosperity.

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