A Preliminary Study on Industry 4.0

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***Abstract*—Companies are facing increased pressure to reduce costs, improve manufacturing performance, and to offer new products and services. Industrial competition demands to offer individualized products and integration of stakeholders in a complete spectrum ranging from customer interaction till production level. In order to enable it, new methods, tools and technologies have to be introduced in enterprises especially at production level. In this paper, we define and explain the term industry 4.0 and a future scenario namely predictive maintenance. To bridge the gap between current production environments and future environments, we describe what is required from technical, technological and human resource perspective? We also provide an approach to solve current pain points and to do preparation to achieve benefits from industry 4.0.**

***Index Terms*—industry 4.0, future manufacturing, IoT, smart manufacturing**

I. Introduction

Companies are facing increased pressure to reduce costs, improve manufacturing performance, and offer new products and services. Information technology (IT) has advanced quite rapidly overall in last decades. Consider the way, how machines and robots operated thirty years ago to performs their fixed routines jobs. Now, those "dumb" robots and machines equipped with more sophisticated sensors [1] can interact and organize operations intelligently. Such developments will have radical impact on industries to perform operations efficiently and effectively. On one hand, the developments in business models and technology used today are quite significant. On the other hand, developments at production level are not significant and are still quite old.

Manufacturing industry is facing various challenges due to increased demand of flexibility, new business demands, and explosion of data. Machines are producing more and more data. Demand for integrating stakeholders (suppliers and customers) in production is also increasing as passage of time. The demand of individualized products or lot size of 1 product and new services to customers requires responsive manufacturing facilities. To meet such demands, organizations are investing resources as reported in the literature [2], [3]. Current manufacturing factories should be more integrated and smarter and provide real time access to stakeholders. Future production environment demands to introduce new technology to remain competitive in future and requires a complete roadmap and long term investments. A smooth-less transition plays an important role for migration. A comprehensive approach is needed for seamless transition in such projects. During this transition, it is important that routine processes of factory should continue as before.

In upcoming sections, we define and explain what industry 4.0 is and why we need changes in our traditional manufacturing systems (due to new business models, companies' competition, and innovation gap). We provide some of the requirements of industry 4.0. We also provide various organizational perspectives and strategies for industry 4.0. We discuss how we should approach to solve pain points and industry 4.0 projects. At the end, we conclude our paper.

II. Industry 4.0 and Future Manufacturing

The first industrial revolution started in the end of the 18th century with the introduction of mechanical machines. The second industrial revolution started in the beginning of the 20th century with electricity and mass production. The third industrial revolution started in early 1970s with introduction of electronics and information Technology. This was the beginning of automation of manufacturing processes and programmed machines and robots started to take the production responsibilities. In order to compete with other uprising countries (like India, China) and offer more value to the customers, developed countries started to apply advance technologies on production level. In USA and some other countries, such initiatives are termed as fourth industrial revolution, Internet of Things (IoT), or next generation systems. Whereas in Germany, this initiative is driven by German government (Bundesministerium für Bildung und Forschung), and referred as Industry 4.0 (industrie 4.0) [4]. The industrial revolutions are depicted in Figure 1. There are various definition exists for industry 4.0 by various groups and companies according to their needs and understanding. They also relate the term with other terms like IoT, Cyber Physical Systems (CPS), Smart Systems, and Digital Factory.

We define Industry 4.0 as a revolution enabled by application of advanced technologies (like IT) at production level to bring new values and services for customers and organization itself. The will also bring flexibility and quality in production systems to fulfill

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demands of new innovative business models and services quickly (service oriented architecture and network communication at production level). The digitalization and virtualization are tools to bring end-to-end services throughout a product life-cycle (design till recycle) and in a cost effective way for customers.

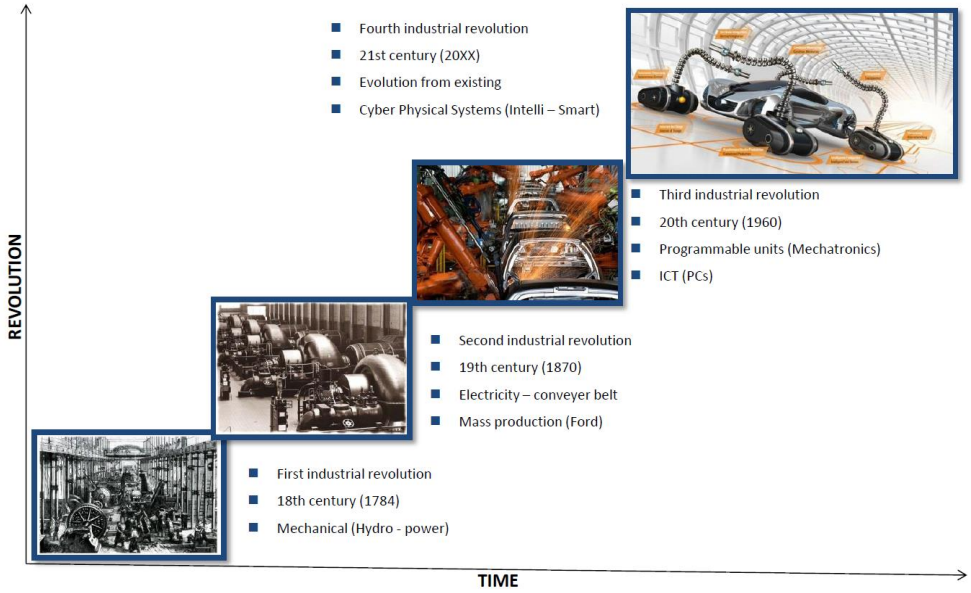

Figure 1. Industrial revolutions.

A formal definition of industry 4.0 is defined in [5] as follows:

"Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes".

Various terms are used in above definition. Here we briefly explain these terms. Powerful autonomous physical systems connected with one another and environment will perform operations intelligently (smart systems). These interconnected systems referred as CPS [6], [7] communicates each other to fulfill the tasks. Cyber-Physical Production Systems comprise smart machines, warehousing systems and production facilities that have been developed digitally and feature end-to-end ICT-based integration, from inbound logistics to production, marketing, outbound logistics and service. The IoT is a network of devices. These devices can be small, e.g., sensor in a fridge or it can be a robot working inside a car manufacturing factory. The no. of IoT devices till 2020 will be around 50 billion, an estimate by Cisco [8]. Such huge amount of connected devices opens up the door for new opportunities and new use cases in every field. Industry and academics will find new use cases and services which can be offered to various industries. Although currently IoT use cases at production level are less and organizations does not know how we can take advantage from it. Collaboration will get more focus in future from industry 4.0 perspective as reported in [5]. In the following, we present one of the future scenarios from industry 4.0 perspectives.

A. Predictive Maintenance

Maintenance of machines is an important area which every manufacturing company has to address. Manufacturing companies try to carry out planned maintenance based on different strategies like operating hours, number of products processed, or after a certain time. A machine condition monitoring system can be introduced to avoid unplanned maintenance. Machines equipped with sensors generates huge amount of data. Such data, e.g., containing machine temperature, vibrations, speed, pressure, state, and other values, records the operating condition in which machine operates. Historical data collected regarding machines operating conditions can play a vital role. Current state of the machine is compared with historical data and with other data in different dimensions (product quality, and wastage data). Models can be developed to predict which part of machine or machine is going to fail or vulnerable in a production environment [9], [10]. Prompt actions can be taken in case of vulnerability to avoid breakdowns. Such actions will increase the reliability of a machine. Predictive maintenance can be performed by seeing when machine is going to fail or which parts should be replaced before machine actually fail.

Machines or hardware manufacturers can collect data from machines to provide remote diagnostics and offer maintenance services from their locations. Such data can also be useful for them to know in which conditions their machines are operating and what they can learn from such data. For example, machine manufacturers can develop next generation of machines for specific industry or buyers segments by understanding their operating needs based on history. Remote setting of parameter or operating conditions or providing early warning in case of machine is over used or wrongly used as compared to what it is made for. They can also send their maintenance staff to repair or diagnose the problem. Such data can be collected by the machines and transmitted to the machine manufacturer. Other option is such data is collected by the production facility and then those enterprises can collaborate to produce or offer better services.

Predictive maintenance helps to minimize factory downtime which in result will improve the production. Planned downtime is less risky, and costs less as compared to unplanned downtime. Although it is quite difficult to estimate the loss due to downtime as it also depends on industry or factors involved e.g. production loss, material loss, low quality of product manufactured, un-productivity of resources, and costs involved to overcome all these issues. The overall cost reduces significantly if it is know which part is going to fail and should be replaced. If production is effected or stopped due to unplanned failure, costs are very high, e.g., averaging around 22,000 dollars per minute as mentioned in a survey [11]. Predictive maintenance will also reduce the overall maintenance costs of machines by keeping machines in healthy and detecting problems at early stage. In addition, safety of the employees can be improved and hazards at production level can be reduced due to mal-functioning. Similarly, business processes can be adapted and optimized based on predictive maintenance to run smoothly.

III. Requirements from Industry 4.0 Perspective

In this section, we discuss what the requirements from industry 4.0 perspective are. First requirement is integration of systems. As discussed earlier, in future, systems will be integrated more with each other and will communicate with each other to achieve common goals. Secondly, the requirement is about real time access to the collaborative environment inside or across enterprise boundaries. Lastly, the requirement we discuss in this paper is related to human resource which is required in future.

A. Integration of Systems

In manufacturing, many systems are involved and all generates data. For example, in production environment, data is generated and collected from different machines sensors, process data, product data, quality data, plant data, logistics data, data from partners, and infrastructure data; all contribute into explosion in data size. Mostly, in organizations such data is stored and processed in separate databases according to each department needs and decisions. Other reason is that these solutions are developed historically and not updated due to fragile nature. It raises in amount of data silos within a company. Data standards are not followed in these silos which results also in heterogeneity and other data problems (redundancy, inconsistency etc.).

Industry 4.0 demands the removal of such data silos and requires systems should be integrated and be able to communicate with each other. Data (without data problems) from single source of truth system will be available to all systems for decision making and further usage. Once systems are integrated, data from shop-floor or from sensors can be added at Enterprise Resource Planning (ERP) level for better optimization or to provide new services to customers. Data engineers can analyze data streams to find new correlation and applying new techniques which were not thought earlier because of data silos within the enterprise.

Integrated systems will also allow to reduce operating costs and efforts to manage such heterogeneous landscape and will simplify the landscape.

B. Real-Time Collaboration Environment

Traditionally, data and information are only exchanged within the enterprise boundaries and often such exchange does not occur in real-time. External providers can not collaborate or optimize their processes as no exchange possibility exists. Reports are made periodically in a predefined format on outdated data, and results are exported into other programs, e.g., in Microsoft Excel, for sharing with partners or decision making.

There is also need of real-time collaboration environments for exchanging data and processes where organizations and customers can collaborate with each other, whether it is related to product design, planning or production environment, within or across enterprise boundaries. The availability of real-time collaborative environment enables organizations to exchange data with logistics partners and suppliers. It will help to keep inventory and processes optimized and will reduce the "Work in progress items". Other benefit of such environment will be to include customer feedback into product design, maintenance services, and overall quality improvement of a product. Business process analysis and process mining [12], [13] within and across enterprise boundaries at process level (with new performance evaluation methods [14]) can also provide new insights for manufacturing intelligence. The real time exchange and analysis of production data and partner's data will enable us to make correct decisions, which leads to cost reduction and improved performance across value chain.

C. Workforce for Future Factory

Organizations are facing shortage of skilled staff due to aging population, employees retiring early or switching jobs. In such cases there is loss of implicit knowledge [15] and experience which employees gained during their jobs. As majority of systems are historically developed and documentation may not exist. If an employees who knows such system retires or switch job then it is a risk for the company. Mostly, the workforce consists of old people who are hesitant to learn technologies or hinder to have change in their routines work. Introducing new techniques or changing their way is quite challenging as they resistant to such changes. This challenge becomes manifold in case of industry 4.0 scenarios where changes are eminent factor. Other issue is to keep the hired persons within organization, as younger ones want to have incentives or in other case they prefer to change jobs.

As described earlier the challenge of finding skilled labor becomes manifold for industry 4.0 as it is also mention in [16]. The future systems will be interconnected in a collaborative environment, future workforce should have knowledge of IT systems, collaborative environments, and be ready to exchange information and work in a team with partners and other stakeholders. Organizations should setup the knowledge

sharing environment to exchange knowledge and best practices within the employees. They should also encourage employees to go for training or advanced courses to deepen their skills [17].

Although there are other important requirements e.g. flexible business processes, security but due to space limitation we did not discuss them in this paper.

IV. How to Approach?

We already provide some requirements from industry 4.0 perspective. As in real industrial setting, all issues can not be addressed at once, so an approach or framework is needed to accomplish the goals, which will address the current problems, and pave the way for industry 4.0. In this section, we will discuss how we should address them with an approach.

There are various perspectives and strategies, depending on the nature of problem, organization can choose from them. As for industry 4.0 changes are required at various levels, so it is important for an organization to decide where they want to focus first. One of the strategies is to address the areas where industry is facing challenges or having problems.

Similarly, there are various perspectives, namely outside-in or inside-out perspective [18], which can be used for road to industry 4.0 depending on the organizations nature.

In outside-in perspective, customers are focal point. Organizations look for what are customer trends and requirement, which innovative services or value added benefit they can provide to customers and on basis of such questions and requirements they design their strategy and build business models. Typical examples of outside-in perspective are offering new business models, products, and services e.g. which data companies or external customers required from production useful for mutual benefit (without losing competitive advantage).

In inside-out perspective, organizations look inside the organization for opportunities how can they better utilize resources and processes to provide new services and products to meet customer's requirements. In inside-out perspective, organizations focus on organization itself and to solve internal challenges, e.g., solving data silos issues, providing real-time data access, standardization, and process optimization, which afterwards, will help to enable industry 4.0 scenarios and benefits. Organizations also have to decide which strategy they want to employ in projects top-down or bottom-up or hybrid one. In top down approach, organization thinks from business models perspective, e.g., what new business models we can enable and what would be consequences on organization. In bottom-up approach, a manufacturing company can start from machines or sensor level analyzing data and resources and look how can they optimize and what data we can integrate at shop-floor or ERP level and what new services we can provide to our customers.

We come up with a step-wise approach as shown in Fig. 2. to manage the complexity and add value for organization in each step.

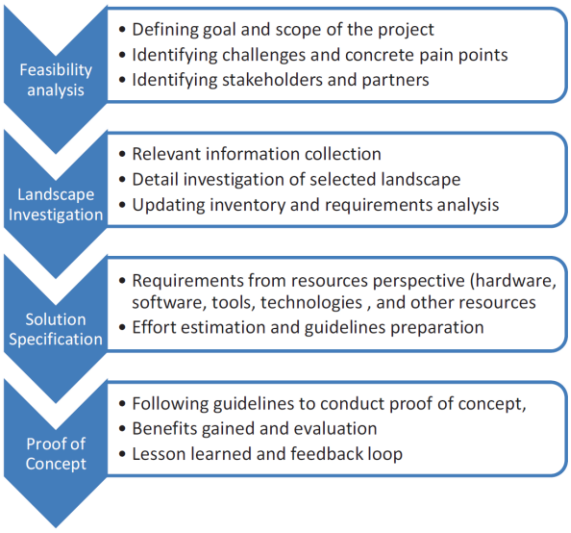

Figure 2. A step-wise approach.

In feasibility analysis, goals and scope of the project will be specified. Organizations will identify who are the stakeholder and partners for a project. They will also identify what are the concrete problems, challenges and high level requirements. At the end of this step, organization knows the challenges and can prioritize them.

Landscape investigation covers the information gathering and detail analysis of selected scope. This step will also give better understanding of their own landscape from organization inventory perspective.

Where as in solution specification solution guidelines will be prepared and what would be required to actually realize the project, whether the organization have required capabilities or not.

In the last step, proof of concept will be performed by following guidelines. Afterwards, evaluation is performed and situation is compared to know what are the benefits and lesson learned. How we can improve the process overall before rolling-out on larger scale.

We provide different requirements for industry 4.0 and discuss perspective and strategies. It depends on the organization which perspective or strategy they will chose to apply in approach.

V. Conclusion

We show the importance of industry 4.0 and how it will enable manufacturing industry to improve and optimize processes with the help of a scenario. In our paper, we discuss what the requirements from industry 4.0 are and how we can address them. We also discuss what kind of perspectives or strategies exists, which an organization can choose for industry 4.0. We provide an approach to solve current challenges and to gain early benefits and prepare organization for industry 4.0 in each step of our approach.

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