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A PROPOSED FRAMEWORK OF GREENFIELD AND BROWNFIELD INDUSTRY FOR INDUSTRY 4.0

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Abstract— The manufacturing industry has become much more competitive as a result of globalization and the scarcity of resources, which has put pressure on businesses to meet rising customer expectations while reducing costs. Because of this, a brand-new industrial revolution—dubbed "Industry 4.0"—has begun. This German-born industrial revolution introduces numerous advances in areas such as process, structure, and information flow. There are several case studies of businesses adopting Industry 4.0, but no overarching strategy or timetable for doing so. The study of how to implement Industry 4.0 is a fresh and uncharted field of study. This paper's goal is to propose the construction of an Industry 4.0 framework for both Greenfield and Brown field businesses by analyzing relevant literature and doing an analysis of existing learning factories. For SMEs looking to implement Industry 4.0, this framework can help guide their development and inform their decisions.

Index Terms—Industry 4.0, Framework, Greenfield Industry, Brownfield Industry.

I. INTRODUCTION

The small and medium-sized businesses (SMEs) that make up the secondary sector of any economy have traditionally been its lifeblood. Small and medium-sized businesses (SMEs) in a developing country like India are considered as a solution for problems like unemployment, poverty, income inequality, and regional imbalances. Based on their capital expenditures for machinery and other equipment, the MSME Development act divides factories into medium, small, and micro enterprises [1]. Medium-sized businesses are those that have invested between INR 50 million and INR 2.5 million in plant and machinery, while small businesses have invested between INR 1 million and INR 2.5 million, and micro businesses have invested less than INR 1 million. Microenterprises, small businesses, and medium-sized businesses in the service sector are those with an initial investment of up to INR 50 million, INR 10 million, and INR 1 million, respectively [2].

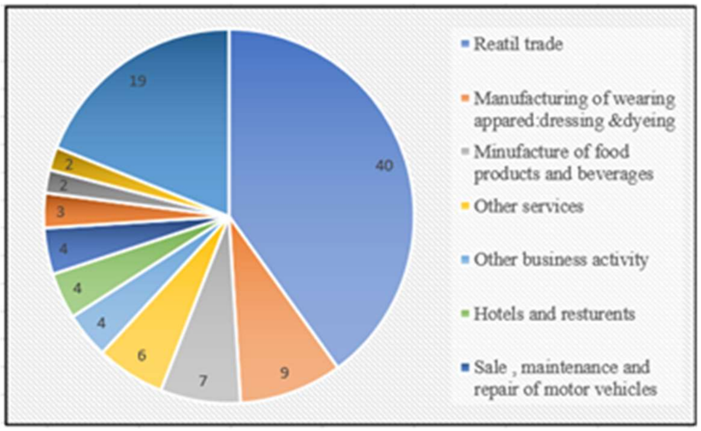


Figure 1: Composition of major sectors in India in which SMEs operate [3].

1.1 Why Are SMEs Important?

There is a wealth of research on the positive effects of small and medium-sized enterprises (SMEs) on economies, including their contributions to expansion, innovation, employment, and the dampening of the informal sector. Figure 1 depicts a straightforward chain of events that shows how lowering regulatory hurdles for SMEs can have a positive effect on the economy as a whole through increased productivity and job creation. These vectors of SME growth and the specific variables that reflect SME sector development are listed in Figure 2, along with the types of interventions used to facilitate them. After that, the results of research into the effects of SME expansion on the economy's growth and employment rates are discussed.

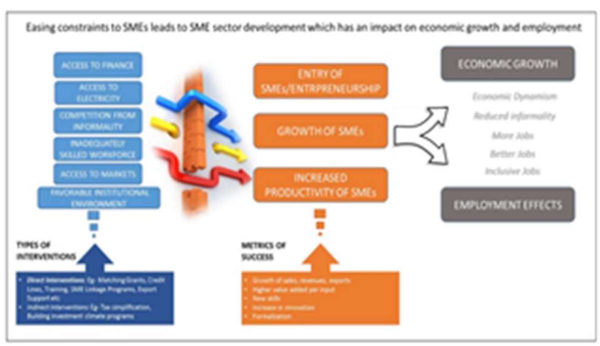
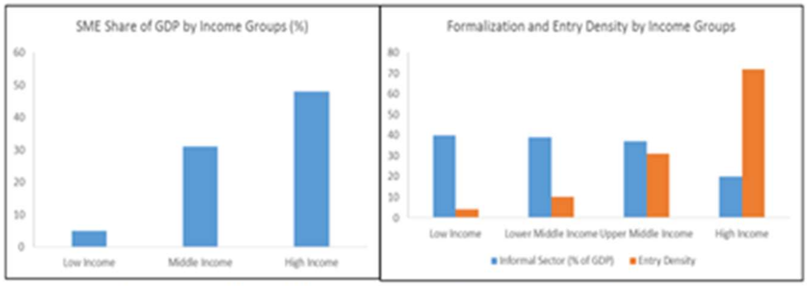


Figure 2: A vibrant SME sector has a significant role to play in the economy [4].

Both developed and developing countries benefit greatly from having a thriving and expanding SME sector. The evidence suggests a positive relationship between the size of the SME sector and economic growth, though the causal impact on long-term growth remains unclear (Beck 2005) [5] .



Source: Adapted from Ayaggari (2007 and 2011). Entry density is defined as the number of newly registered limited liability firms per 1000 working age people- ages 15 to 64. (World Bank Entrepreneurship Database)

Figure 3: Relationship between SME growth and GDP, Formalization and Entry Density.

As an emerging market, India's manufacturing sector is crucial to the country's economic development because it accounts for a disproportionately large share of GDP growth. Companies in this sector recruit their best employees from universities, but some new hires prove to be incapable and unproductive in their first few years on the job. Some recent grads experience "culture shock" when they enter the workforce. Some industries are hesitant to hire recent college grads because they see them as a liability during their first few years on the job. Sometimes businesses will go above and beyond to provide employees with the training they need to perform at a satisfactory level.

Industry 4.0 (I.4.0) refers to a set of developments, primarily in the areas of digital technology and manufacturing, that have brought about profound changes in the business world. There are numerous case studies of businesses adopting Industry 4.0, but no overarching framework or timetable for doing so. Methods of implementing Industry 4.0 remain an active and underexplored field of study.Implementation projects can begin with Industry 4.0 as a low-risk entry into an adapted digitization strategy. While larger corporations have already incorporated comprehensive digitization initiatives into their core business strategy, smaller businesses often struggle to put the industry 4.0 paradigms into practice. It is critical to develop concepts tailored to SMEs because of the enormous leverage effect they have as the backbone of the economy. Any business, no matter how large or small, can benefit from adopting a digital transformation strategy. So, in this paper a generic framework for industry 4.0 is proposed for green field and brown field SMEs. The proposed framework can help SMEs successfully embrace industry 4.0.and may profit from adopting this framework. This may help them not just financially, but also in keeping up with the rest of the industry.

II. LITERATURE STUDY

The term "Industry 4.0" describes the modern fad toward greater computerization and automation in the manufacturing process. It's a hot topic in conversations across all demographics, from the general public to business leaders to academics. Since it was first brought up in 2011 by the German government, it has risen to the forefront of many research institutions, universities, and businesses across the globe, including in India [6]. The reason for this is that by 2025, it is expected that the positive effects of Industry 4.0 will add up to about 20% of India's GDP [7]. Industry 4.0 has become a hot topic of study, and for the first time in history, an industrial revolution is being predicted a priori; as a result, the concept's true meaning and definition have become muddled [8]. Although there is no universally accepted definition, many different but related concepts and criteria have been collected and discussed.

2.1 Historical industrialization

According to Bauernhansl,[09] the first industrial revolution was the mobilization and mechanization of industry utilizing water and steam power. Moreover, Bauernhansl [09] emphasize that the discovery and development of electric power helped usher in mass manufacturing during the second industrial revolution". Multiple authors [10,11] agree that the 1970s through the early 21st century constitute the era of the third industrial revolution, sometimes known as the digital age. The development of miniaturized electronics and electrical components made possible the widespread use of mobile devices, portable computing, the Internet, and electronic data transmission. Sequentially, the results of the mechanization, electrical, and information technology revolutions may be summed up as the first three industrial revolutions (IT). Since IoT and IoS have been implemented into manufacturing, the fourth industrial revolution has begun, as stated by Kagermann [11]. Figure 4 displays, at a high level of generality, the history of the several industrial revolutions".

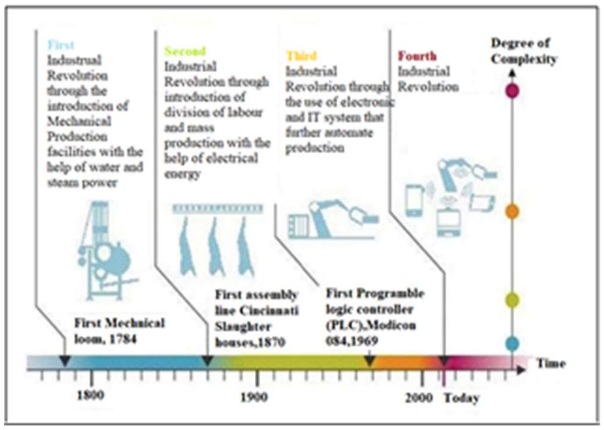


Figure 4: Industrial revolution time line [14].

Industry 4.0 is a German government tech effort that uses the IoT to encourage and drastically speed up computerization and industrialization in that country. The term "Industry 4.0" refers to the adoption and widespread use of cutting-edge methods in production, data transfer, and automation. In order to properly define the effects of some of these innovations, they have been categorized under more general terms such as the "internet of things," "internet of services," and "cyber-physical systems" (CPSs). This concept, as it is further stated, holds true for any and all electrical devices that have an internet connection and may be manipulated online as either sensors or actuators. While the IoT provides "things" with access to the internet, the IoS provides such "things" with access to online services like Twitter [13]. Last but not least, CPSs are the cyberspace where people, machines, and the IoT all collide. Hermann et al. [14] claim that CPS are installed in the smart, modularly built factories of Industry 4.0, where they keep tabs on physical processes, simulate reality, and make choices without human involvement. Over the IoT, connected physical systems (CPSs) cooperate with one another and communicate data in real time. Value chain actors may provide and access services from inside and across their own organizations through the IoS.

III. INDUSTRY 4.0 MAIN COMPONENT

Hermann’s [15] quantitative literature review of 2015, an effort to describe Industry 4.0, offered evidence for identifying the core concepts at play in this movement. The process began with the collection of Industry 4.0-related keywords. With this in mind, Hermann [15] not only defined Industry 4.0 in German but also provided an English translation of the term. Hermann [15] found 51 articles after compiling the most common terms associated with Industry 4.0. They used a forwards-and-backwards search of each article in these 51 publications to compile Table 2. in the end, they made the choice to ignore the rest and concentrate on only four crucial features of Industry 4.0. According to the authors' analysis, M2M and smart products cannot be considered in isolation from the rest of the industry 4.0 environment. Big data and cloud computing, as suggested by Hermann [15], are not separate parts of Industry 4.0 but rather data services that make use of data offered by Industry 4.0 implementations. The next part goes over the last four elements: smart factories, IoT, CPSs, and Ios.

Search Term	No. of Publications in which search term occurred
Cyber-physical systems	46
Internet of things	36
Smart factory	24
Internet of Services	19
Smart product	10
Machine-to-machine	8
Big data	7
Cloud	5

Table 1: Industry 4.0 keywork associations [16]

Keyword 1	Keyword 1
Industry 4.0	Cyber-physical systems
	Internet of things
	Smart factory
	Internet of Services
	Smart product
	Machine-to-machine
	Big data
	Cloud
	M2M (machine-to-machine

Table 2: Industry 4.0 components[16]

IV. INDUSTRY 4.0 BUILDING BLOCKS OR PILLARS OF TECHNOLOGICAL ADVANCEMENT

The underlying technologies and techniques that are facilitating the transition to Industry 4.0 might be thought of as the foundational elements, or pillars, of technological progress". These technologies already exist but, in some cases, need to be modified and enhanced so that they may be adapted to the unique requirements of each user instances Boston consulting company [17]. They are already in use in industry, but are often found in isolated examples, which is why the term "Industry 4.0" was created. Industry 4.0 is the name given to the next phase of manufacturing that this technological confluence has brought in.

- Bigdata analytics,
- Embedded electronics,
- Simulation,
- Cyber-security,

- Cloud computing,
- Additive manufacturing,
- Augmented reality
- Digital factory and
- Communication technology

In this section, we examine nine areas of current tech that serve as the bedrock of Industry 4.0. Industry 4.0's core features, as we've seen, require these supplementary frameworks to operate properly. Some of the components described here will be included in the core components of Industry 4.0 deployment by necessity. In what follows, we'll go through seven guidelines for designing for Industry 4.0.

V. STUDYING VARIOUS LEARNING FACTORY AND COMPOSITION OF LEARNING FACTORY

5.1 Learning factories

According to Abele et al. [18], In contrast to traditional factories, a learning factory models its procedures and machinery after those of small and medium-sized enterprises (SMEs). In a learning factory, participants are immersed in a production setting that closely mimics the real world, with only the most basic simplifications allowed.

Elements of Learning Factory [19]

Researchers dissected and studied numerous learning factories to identify its constituent parts. There was the Darmstadt Learning Factory in Germany, the ESB Logistics Learning Factory at the University of Reutlingen, the Budapest University Learning Factory, the Vienna Learning Factory, and the Split Learning Factory in Croatia. Elements of a learning factory were defined for the purposes of this project based on findings from analyses of existing learning factories.

System nodes:

A user instance that can be modified to perform a specific task within a system is called a system node. It represents the completion of earlier steps. Information, processes, materials, and resources all converge at nodes in a system. A toy factory's assembly line, for instance, might include such a station. Information, processes (in the form of assembly), materials, and resources (human labor) all converge at the assembly station.

Objects:

An object is the smallest physical entity that contributes to, enhances, or otherwise modifies a process function (a node in the system). The smallest physically independent element in a learning factory is the objects themselves. An inexpensive microcontroller like an Arduino or programmable logic controller (PLC) is one such thing.

Technologies and software:

The technologies and programs in question are those needed for the various components of a system to do their jobs. Since most physical objects can't do much of anything without some sort of accompanying software or technology (and since some physical objects can be thought of as technologies in and of themselves), this category is closely related to the two preceding ones. This category is distinct from the others because many things and system nodes can have various technologies or software, which can then be modified using various methods and result in "new" things.

VI. DIMENSIONS FOR INDUSTRY 4.0

By analyzing the various models, we were able to determine what fundamental skills are taught in learning factories all over the world. Courses that are taught in learning factories are listed in work by Kreimeier [20] and Abele et al. [21]. These classes were turned into skills that were taught in places called "learning factories." The first level of the framework is made up of these skills. And more research led to the discovery of groups of elements that are common to both learning factories and small and medium-sized enterprises (SMEs), since learning factories are likened to SMEs.

The various components of a learning factory were defined during the course of the study as follows [22]: System nodes; objects; technology; software. The dimensions of the framework were organized according to these classes.[23]

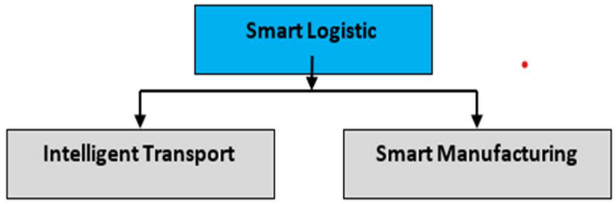
Competencies
Industry 4.0 applications
Methods
System nodes
Objects
Technology and software

6.1 Connecting the dimensions

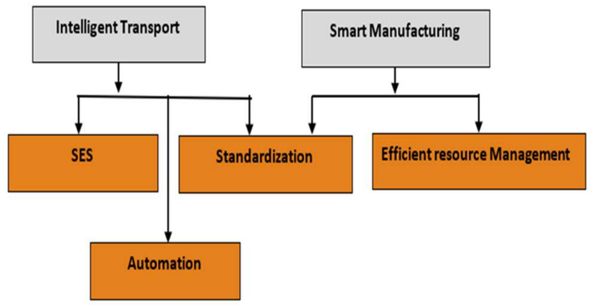
Our research into different types of "learning factories" led us to pinpoint the following six crucial factors [19] for successfully introducing Industry 4.0. Elements relevant to Industry 4.0 were included in each dimension to serve as concrete guidelines for its adoption.

Decision support for full frameworks can be provided, with an emphasis on Industry 4.0 (greenfield design), but the elements and dimensions discussed above can also be used in the redesign of SMEs or learning factories that want to incorporate Industry 4.0 with the elements they already have (Industry 4.0 redesign). Learning factories that already exist and want to improve their operations by incorporating particular applications from the Industry 4.0 standard can also use dimensions (Industry 4.0 greenfield design) to do so.

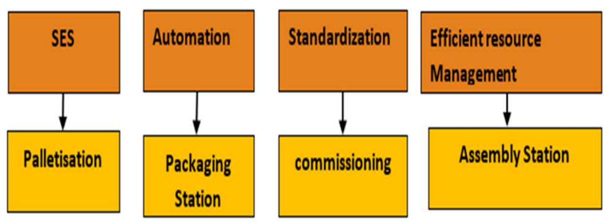
In Figure 5a, we see an example of the first phase. In the second stage, as seen in Figure 5b, we connected the dots between the industry 4.0 uses we'd uncovered in the first stage and the appropriate approaches. Next, we connected the dots between the identified techniques and system nodes, as illustrated in Figure 5c. In Figure 5d, we see the result of the fourth phase, which was to determine which objects are needed to execute each individual method at each individual node in the system. Figure 5e shows the last stage, which was to connect the objects to the enabling technologies/software that met their other criteria. It was then done again for each competence that had been identified [24].



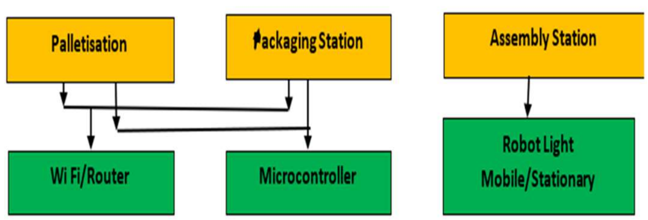
(a) Competencies and Industry 4.0 applications



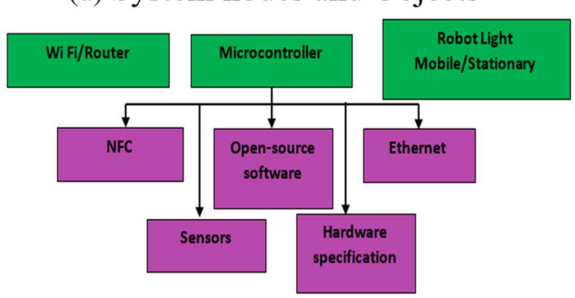
(b) Industry 4.0 applications and methods



(c) Methods and system



(d) System nodes and Objects



(e) Objects and technologies/software

Figure 5: Expansion of layers in Framework [24]

VII. INDUSTRY 4.0 PROPOSED FRAMEWORK

Greenfield design

To include Industry 4.0 applications into a brand new, soon-to-be-built plant, a user may request a greenfield design of an Industry, in which case the design would be carried out in line with the framework from the competences dimension up to the technologies/software dimension. The user would then choose the most important skills and knowledge that the learning factory should emphasize or highlight. After settling on a set of essential skills, the user should examine the tree diagrams, which show how those abilities relate to the other dimensions. Figure 6 is a branching diagram depicting one possible path to proficiency using lean tools. The figure's dimensions are shown at the figure's top. In this particular instance, the user will follow the supplied coloring scheme and work from the left side of the tree diagram to the right side. A skill can be taught or used in the learning factory once the user can construct a left-to-right path using only green, blue, and/or orange pieces. This is accomplished through the selected Industry 4.0 application. When a branch's color is red, it means that choice is not viable. These errors show that the user is not competent in that particular subset of the competence and hence cannot use the tool for implementation or instruction [25].

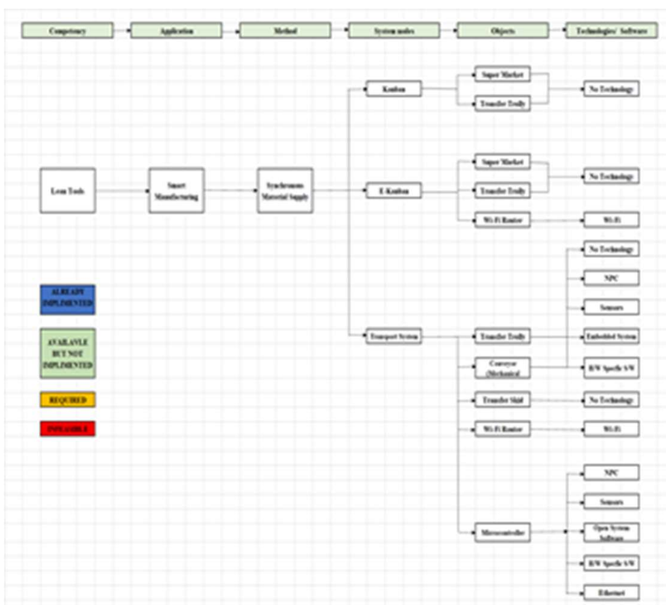


Figure 6: Industry 4.0 Green Field design

Brownfield design

If a factory already exists but the user needs guidance making decisions about its reconstruction to accommodate Industry 4.0 features, a redesign is required. As in the greenfield design example, in Figure 4.6 the user begins at the right side of the tree diagram and works their way to the left, adding colors in the manner explained above. With this method, the user will have an easier time figuring out what resources are currently available to them and what they may be put toward. It has already been established that the user requires a smooth transition from the realm of technologies/software to the realm of business. the relevant Industry Only green, blue, and/or orange elements are used in 4.0 applications and skill dimensions. 4.0 implementation and required skills. Working through to the competences dimension is necessary to realize the ultimate goal of this framework application, which is to improve present operations and/or the skillsets taught via the designing and deployment of Industry 4.0 applications.

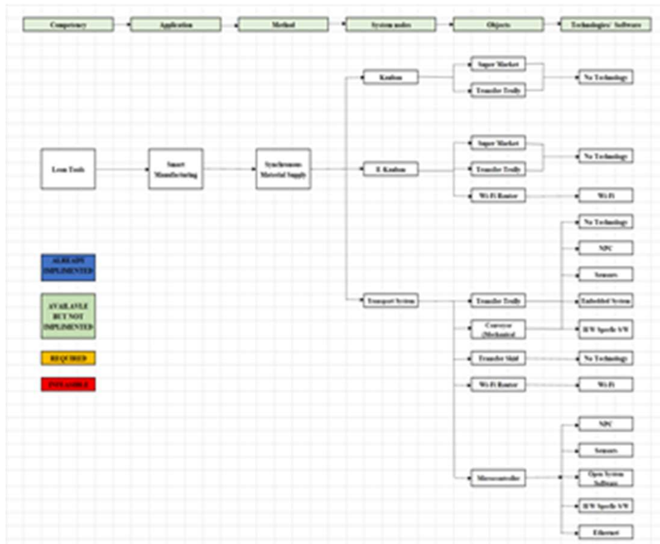


Figure 7: Industry 4.0 Brownfield design

Figure 7 is a tree diagram depicting the steps we will take to implement our vision of Industry 4.0. We'll begin at the left and work our way to the right. Again, the items are colored according to the given color-coding key. The user may construct the industry 4.0 application in the same way they would construct any other framework application once a direct line can be formed from the application to the technologies/software associated with the application.

VIII.CONCLUSION

In this paper a general and methodological industry 4.0 framework for "greenfield" (completely new) is proposed and also it proposes a frame work for “Brownfield design” which involves implementing industry 4.0 features into an already established small and medium-sized enterprise. This Framework can be enhanced by adding more dimensions that would make it possible to adapt the structure for a broader range of uses.The proposed framework can help /profit small and medium-sized enterprises (SMEs) from adopting this framework. This may help them not just financially, but also in keeping up with the rest of the industry.

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