Framework for Manufacturing in Post-COVID-19 World Order: An Indian Perspective

S. G. Deshmukh¹ · Abid Haleem²

Received: 28 April 2020 / Accepted: 19 May 2020 / Published online: 6 July 2020
© Global Institute of Flexible Systems Management 2020

Abstract

COVID-19 pandemic has created a colossal disruption all over the globe, especially in Europe, the USA, China, India, and many developed economies. The production supply chains have been massively disturbed. It is estimated that a significant number of Fortune 1000 firms have been severely affected by the pandemic. Manufacturing companies operating in and through India are also affected by COVID-19. However, COVID-19 also offers an opportunity to revisit the competitiveness of Indian manufacturing. Traditionally, India's manufacturing growth has been based mostly on its domestic market. The disruptions due to COVID-19 are likely to offer new models of working and at the same time, opportunities to build capabilities and explore new international markets. The paper gives a perspective on Indian manufacturing involving various stakeholders such as industry associations, professional bodies, academic institutes, and industry to tackle the issue of enhancing manufacturing competitiveness. In a post-COVID-19, India will have to decide a mix of conventional manufacturing facilities, the automated special purpose, and industry 4.0. One perspective is to have an increased level of automation and implementation of Industry 4.0, with localized skills and global aspirations and another view is to have traditional manufacturing facilities that can ramp up its capabilities to satisfy increased demand of products. This paper presents a conceptual framework to assess Indian manufacturing.

Keywords Competitiveness · Flexibility · PEST · Industry 4.0 · Manufacturing · Medical sector

Introduction

COVID-19 pandemic has created an enormous disruption all over the globe. It has resulted in extensive human casualties all over the globe, especially in Europe, the USA, China, and many developed economies. The abrupt stoppage of demand has disrupted the standard supply chain. Furthermore, along with surge demand for medical products, the production, and consumption supply chains have been massively disturbed. It is estimated that among the Fortune 1000 listed companies, 94% have been affected by the COVID-19 (Fortune 2020). Due to hyper-connected supply chains, many of the companies are affected by this pandemic. Prolonged lock-down, stoppage of air flights in several countries, and closure of

manufacturing plants have contributed to the disruptions in supply chains all over the globe.

- COVID-19 supposedly originated from Wuhan in December 2019 where Wuhan is significant to many global supply chains.
- China contributes to about 19% of world GDP (Statista 2020) China is also a traditional base for manufacturing and home for high technology (optoelectronic technology, pharmaceuticals, bioengineering, and environmental protection) and modern manufacturing (automotive, steel and iron manufacturing).
- There are lock-down and closure of plants and stoppage of travel/transportation across the globe.
- The domino effect of plant closures and supply shortages across the supply network has resulted in significant supply chain disruption.

✉ S. G. Deshmukh
deshmukh.sg@gmail.com

¹ Mechanical Engineering Department, Indian Institute of Technology Delhi, Delhi, India

² Mechanical Engineering Department, Jamia Millia Islamia, Delhi, India

India is no exception to this. Manufacturing companies operating in and through India are also affected by COVID-19 (Haleem et al. 2020). The magnitude of the impact on a global

level can be gauged from the statement of the World Trade Organization (WTO) which has projected that global trade in goods is set to decline steeply between 13% and 32% in 2020, as countries across the world are struggling with the COVID-19 pandemic (WTO 2020). The enormous disruptions caused by COVID-19 are unparalleled. These disruptions have enormous implications for both academicians and practitioners. COVID-19 has also impacted the Indian economy and various other manufacturing and service sectors (Pratheesh and Arumugasamy 2020). Haleem et al. (2020) present various academic areas that are likely to be impacted by COVID-19. They highlight implications for Manufacturing which will be triggered by Industry 4.0 and other considerations.

The objectives of this paper are to:

- highlight the necessity for understating the vital role of manufacturing in Indian context;
- develop a framework to position manufacturing in a proper perspective post-COVID-19 scenario.

The National Significance of Manufacturing Sector

Manufacturing has been recognized as the main engine for vibrant growth and the creation of the nation's wealth (Rele 2020). The significance of manufacturing can be assessed from the following:

- (a) The impact of manufacturing activities goes far beyond the “manufacturing” sector. Manufacturing creates and sells goods to other sectors (Pharma, agriculture machinery, capital goods, etc.) and in turn, buys materials and services from them (Deshmukh 2016).
- (b) Steel, automotive sector, light engineering, pharmaceuticals, food processing, electronics, machine tools, textiles, etc., are the major manufacturing sectors where India has developed considerable competence (Deshmukh 2016). Manufacturing triggers demand everything from raw materials to intermediate components/products.
- (c) The manufacturing sector has the potential to offer employment opportunities directly or indirectly. This is especially important given the severe reduction in employment all over the globe due to COVID-19. In view of WHO (2020) guidelines for the necessity of the medical equipment, India is poised for a big market for the manufacturing of medical items.
- (d) Manufacturing has a synergistic and cascading effect on many other sectors such as agriculture. Through more intensive efforts on agro-based Industries, given the rural population and reliance on agri-sector, the manu-

facturing sector is going to play a significant role in the post-COVID-19 scenario.

- (e) Retail services are mostly the act of using manufactured goods. India is ranked No. 2 in Global Retail Development Index (GRDI) in 2019 and the retail industry contributes to about 10% of the GDP (Invest India Statistics 2020).
- (f) The entrepreneurial and enterprising mindset has stimulated the rise of low-cost manufacturing clusters in India (for example—Manufacturing cluster in Ludhiana (in Punjab), Pune–Nasik (in Maharashtra), Coimbatore (in Tamilnadu). These clusters have contributed significantly. The growth effects of such industrial clusters and its implications for India are highlighted in (Narayana 2014). Such clusters have also helped to reduce regional disparities.
- (g) Manufacturing's role in terms of employment creation is crucial. The available network of Information and Communication Technologies (ICT) has helped in providing necessary technical support. The National Policy on Skill Development has set a target of skilling 500 million people by 2022 (National Policy for Skill Development & Entrepreneurship 2015). Of course, this target may be revised given COVID-19 disruptions.

Given the strategic importance of the manufacturing sector in India, it must adjust to the challenges posed by COVID-19.

Most of the economies that enhanced competitiveness leveraged manufacturing effectively and countries in East Asia provide excellent examples of this (Singh et al. 2007). In one of the early studies, Dangayach and Deshmukh (2003) elaborated on the strategic role of manufacturing in the Indian context. Momaya and Anuprita (2006) have assessed the competitiveness of Indian Auto manufacturers. Bhawsar and Chattopadhyay (2015) have given a synoptic view of various connotations attached to competitiveness and reviewed the relevant literature on competitiveness.

Deshmukh (2016) had given directions for research in manufacturing competitiveness.

Deloitte (2016) is an outcome of the study done by Deloitte's Global Manufacturing Industry group and the U.S. Council on Competitiveness (a leadership organization in the U.S. comprised of CEOs, university presidents, and labor leaders). This study is designed to help global industry executives and policymakers evaluate drivers that are key to company and country-level competitiveness as well as identify which nations are expected to offer the most competitive manufacturing environments through the end of this decade.

In this paper, the above study is taken as a reference due to the following reasons:

- (a) The study is based on the responses of more than 500 chief executive officers and senior manufacturing executives around the world.
- (b) The 2016 study is a sequel to previous studies done in 2010 and 2013 which had attracted lot of attention from the practitioner and policy planners. The methodology is consolidated based on previous studies.

According to the above study, India is ranked at 11th position and projected at the fifth position by 2020. About 62% of global manufacturing executives surveyed rank India as highly competitive on cost, closely mirroring China's performance (Deloitte 2016).

This paper explores some of the opportunities for enhancing the competitiveness of Manufacturing. A synergistic policy framework needs to be developed at the national level involving various stakeholders such as industry associations, professional bodies, academic institutes, and industry to tackle the issue of enhancing manufacturing competitiveness from all perspectives.

Imperatives Due to Post-COVID-19 Pandemic Scenario

Post-COVID-19, countries will try to turn inwards by producing at the national level. Post-COVID-19 period marks the effective start of deglobalization. Corona is infecting countries and regions with a delay of some time. China has opened its economy and may get substantial benefits in the long term. Similarly; other countries would be opening from lockdown and resume regular industrial operations one by one. In this context, the following observations are in order:

- (a) Southeast Asian countries will follow China after a delay like Hong Kong, Korea, Taiwan, then some parts of the European Union will open, then the USA and then India and then other African countries may follow. There will be a gradual opening of facilities and industry. People with limited economic resources and with months of lockdown would see a reduction in demand for products and services. Many employees are likely to become jobless, and effectively demand will become much less.
- (b) Supply line would also be disrupted with the non-availability of labor, and it will take time to resume and become fully operational. Many items would lose their shelf life and will have to be returned to the company. The reverse supply chain will have to work faster and be effective.
- (c) The manufacturing organizations need to reorganize their supply chains, reorganize their workforce, and

even suppliers. It may be equivalent to developing a new supply chain.

- (d) China may face minimum disruption at the supplier level, but global demand for "Made-in-China" items may temporarily shrink.
- (e) This is an opportunity for Indian manufacturing to take proactive steps and push their products into the global market. Initially, these may be medical items (like ventilators/respirators) Later, the competence and goodwill gained may be utilized to produce other items as well. The disruptions due to COVID-19 are likely to offer new markets. It has triggered the demand for a variety of products. For example, Ventilators, respirators, PPE, Medicines, and associated items as required for the medical sector, items from the pharmaceutical side, etc. It is to be noted that healthcare systems are going to be the major driver for Indian Manufacturing
- (f) It is evident that the disruptions caused due by COVID-19 also calls for a relook the way the Indian manufacturing sector has set its priorities and the way we measure performance. COVID-19 also offers an opportunity to revisit the competitiveness of Indian MSME's, and consequently, we need to rethink for our manufacturing policy. Traditionally, India's manufacturing growth has been based mainly on its domestic market with its limitations and potential. However, during the last decade, the industry became too dependent on Chinese products. China has emerged as one of the largest raw material and component suppliers.

Framework Development

In India, there is also the availability of competent quality human resources. Technology has its role to play in achieving economies of scale and improving quality. Improvement in quality is manifest in many of the initiatives such as the adoption of ISO9000/14000, 5-S, Lean manufacturing practices, TPM (Total Productive Management) practices, etc. The number of Deming prize winners' companies (32 out of 72 companies outside Japan are Indian companies winning this prestigious prize since the year 2000!) is an indicator of this. The use of appropriate technology in the manufacturing process has made the process competitive. Innovation and competition make it inevitable for the manufacturing sector (especially, MSMEs) to equip with new technology and modernization. It is expected that COVID-19 will accelerate this process.

The major challenge is to continuously provide innovative and customized products using the best available process technologies (Singh et al. 2007). According to Ajitabh and Momaya (2004) in such a kind of environment, a firm's competitiveness will depend on its ability

to provide goods and services more efficiently than others involved in the marketplace. It is also to be noted that the practice, research, and literature on competitiveness are still in the infantile stage, and have enormous scope for improvements, especially in the Indian context (Momaya 2019).

Looking at the strategic imperatives of the post-COVID-19 scenario, and suggestions given in the earlier section, it was felt necessary to use PEST framework to identify dominant factors. PEST analysis stands for ‘Political, Economic, Social and Technological Analysis’ (Johnson and Scholes 1993) to indicate the external influences viz., Political, Economic, Social, and Technological factors with reference to Manufacturing. PEST analysis is used as a strategic tool to understand the environment, possible growths, political stability of the state, business position, prospects, environmental opportunities and threats, etc. According to Ward and Rivani (2005) PEST analysis assumes that specific external and indirect circumstances that characterize the business environment can influence the organizational capacity to produce value. PEST analysis provides a “satellite view” to assess the external environment (Ward and Rivani 2005). It is particularly relevant for the manufacturing sector post-COVID scenario. It is envisaged that this analysis will also help identify the proper focus.

The following qualitative framework is used here.

- (a) The drivers are identified based on the competitiveness drivers of Deloitte (2016).
- (b) The PEST analysis is used to identify various factors vis-à-vis the drivers.
- (c) Based on these, roles for various actors are identified to make Indian manufacturing as competitive.

This framework is depicted in Fig. 1.

This framework is explained below:

Fig. 1 Schematic of the framework

Table 1 Drivers for global manufacturing competitiveness
Source: Deloitte Report (2016)

D1	Talent	D7	Physical infrastructure
D2	Cost competitiveness	D8	Economic, trade, financial and tax system
D3	Workforce productivity	D9	Innovation policy and infrastructure
D4	Supplier network	D10	Energy policy
D5	Legal and regulatory framework	D11	Local Market attractiveness
D6	Education workforce	D12	Healthcare system

Drivers for Manufacturing Competitiveness

According to Deloitte (2016), India offers a highly skilled workforce and a particularly rich pool of English-speaking scientists, researchers, and engineers which makes it well-suited to support high-tech sectors. The Indian government also offers support in the form of initiatives and funding that focus on attracting manufacturing investments. Table 1 gives the drivers for global manufacturing competitiveness as reported by Deloitte (2016).

As organizations internationalize and expand their global manufacturing footprint, they must consider the multiple factors that underpin the competitiveness of a country. To understand and explain the dynamics of a country’s overall manufacturing competitiveness, they must be examined as two major, inextricably linked forces—market and government. Deloitte (2016) identifies the following 12 drivers arising out of the complex interplay between market and government forces.

PEST Analysis

The PEST analysis examines four critical categories of external environmental factors, namely:

Political factors (P): these refer to different forms of government interventions and political activities in an economy. In the COVID-19, scenario, political factors are going to play a significant role.

Economic factors (E): these refer to the macro-economic policies and conditions of the external environment. The entire economy is severely affected by COVID-19. The economic policy and directions are going to decide the thrust given to the various sector.

Social factors (S): these refer to social, cultural, and contextual demographic factors of the external environment. COVID-19 has affected the social structure and it has also the potential of affecting the work culture.

Technological factors (T): these refer to technology-related activities, technological infrastructure, technology incentives, and technological paradigms that may affect the external environment. Technology is going to play a vital role in the post-COVID scenario.

In line with the imperatives listed in Sect. 3 and the identified drivers above, the following suggestions are offered

for each of the drivers of competitive manufacturing and are shown in Table 2.

Based on the above and looking at then issues due to COVID-19, Table 3 presents the PEST analysis. This table also highlights the factors governing the drivers for global manufacturing competitiveness.

It is evident from Table 3 that the technological factor is the most dominant factor responsible for nine drivers

(D1, D2, D3, D4, D6, D9, D10, D11, and D12) of global manufacturing competitiveness. This is also in line with Dewangan et al. (2015) who have identified “Technological Opportunities” as one of the enablers for achieving competitiveness of Indian manufacturing.

This has motivated to study these factors in more detail and how do we leverage the same given COVID-19 and articulate roles for various agencies as envisaged in Fig. 1.

Table 2 Suggestions for enhancing drivers of manufacturing competitiveness

Driver	Description	Suggestions
D1	Talent	Identify talent and pool them Government agencies, technical institutes, industry to play a significant role in capacity building
D2	Cost competitiveness	Government to offer incentives for industry Industries to pool resources and consolidate on a bigger scale to leverage economies of scale and scope
D3	Workforce productivity	Productivity to be linked to workers Incentives to be offered Digital solutions to improve productivity
D4	Supplier network	Identify a network of Indian suppliers Industry associations to play a significant role in facilitating the supplier network.
D5	Legal and regulatory framework	A revised regulatory framework for helping first MSME then large Indian corporations Enabling and proactive rules for entry and exit of companies into the market and safeguarding interest of Indian origin companies Labor laws being reformulated for enhancing ease-of-doing-business Global companies may not be an immediate concern
D6	Education workforce	Reskilling in healthcare, biomedical, and other areas of national interest Education and training in Industry 4.0, low-cost automation and traditional manufacturing Continuous up gradation of trainers/teachers
D7	Physical infrastructure	Government to develop and give buildup facilities free to MSME More stress on using existing infrastructure Try to focus on developing IT infrastructure in remote areas
D8	Economic, Trade, Financial and Tax system	Credit policy for improving employment Less credit for large corporations Tax rebate on helping the masses in this testing time of COVID-19 Tax holiday for certain specified items
D9	Innovation policy and infrastructure	National innovation Policy to emphasize medical items Large scale solutions to be nurtured at the highest level A multi-disciplinary task force to be formed for monitoring the progress
D10	Energy policy	More focus on energy-efficient policies With cheap oil, energy cost may decrease substantially Localized energy sources to be leveraged
D11	Local Market attractiveness	Local markets to be developed and the Government must facilitate the development of proper markets in small cities and tehsil and at the village level. Proper infrastructure to be built for this. People may move to less congested places and may return to villages Small organizations will have to develop better supply chains Firms agility/flexibility and ambidexterity will play a significant role in balancing local market needs vis-à-vis global market demands. This will help in leavening niche market segments in India/Asia
D12	Healthcare system	Enhance investment in this sector Modernization of existing healthcare sector Focus on quality services Develop state-owned excellent healthcare infrastructure throughout the country even accessible at the village level Healthcare to be an affordable service

Table 3 PEST analysis for manufacturing competitiveness drivers

Factor	Brief determinants of this factor	Responsible for Global Manufacturing Competitiveness Drivers (as in Table 1)
Political	Political climate and stability Strong political leadership Political willingness Good law and order situation Cooperation between the public and private sector Conducive. Taxation for MSME, Thrust on developing agricultural sector, etc. Emphasis on “Make-in-India”, Start-up India, Digital India programme	D5: Legal and Regulatory Framework D10: Energy Policy D12: Healthcare system D7: Physical Infrastructure
Economic	Government’s monetary and fiscal policies COVID-19 has attracted the attention of Reserve Bank of India (RBI) RBI’s fiscal package to support industries during COVID-19 Liberal. Money supply and Institutional Lending Adequate Stock of food grains and economic conditions Government concerned about the GDP growth	D2: Cost competitiveness D3: Workforce productivity D7: Physical Infrastructure D8: Economic, Trade, Financial and Tax system
Socio-cultural	Social traditions based on strong family systems Entrepreneurial, values and beliefs COVID-19 has stimulated the entrepreneurial spirit COVID-19 has attracted e-services/Work-from-home habits Cohesiveness in the entrepreneurial class High Level and standards of technical education Strong industry associations like ASSOCHAM/FICCI/CII who may act as facilitators	D1: Talent D3: Workforce Productivity D6: Educational workforce D12: Healthcare system
Technological Innovations	COVID-19 attracted techno-innovations (manufacture of ventilators by traditional manufacturing companies is an example!) Realization of huge global market availability for tech-based medical products Availability of computing power required for the design and manufacture of products using CAD, CAM, CIM Web technology is changing the business models and challenging the traditional structure. Technological acquisition and dissemination Emerging acceptance of Industry 4.0	D1: Talent D2: Cost competitiveness D3: Workforce Productivity D4: Supplier Network D6: Education workforce D9: Innovation Policy and Infrastructure D10: Energy Policy D11: Local Market attractiveness D12: Healthcare system

Role of Various Actors

Based on the drivers, their interplay with various components of PEST analysis, roles are identified for various actors (such as Government, funding agencies, industry association, educational institutes, etc.). The “actor” can be individual managers, or groups, departments or class of actors such as suppliers, competitors, government representatives, consultants, management, employees, etc. This is given in Table 4.

Some observations are in order:

- (i) The following examples are indicative of efforts done at educational/technical/research organizations and facilitated by funding agencies in countering COVID-19.
 - (a) Indian Institutes of Technology are enhancing their innovation and research efforts to help India

fight COVID-19. This has resulted in some interesting products. IIT Madras and IIT Kanpur have built drones for surveillance and IIT Ropar has produced robots to deliver food and medicines to patients in hospitals and quarantine zones. These innovations are in various stages of development. Other products include low-cost hazmat suits, real-time COVID-19 testing devices, ventilators, and rapid diagnostic kits developed by the IIT Kharagpur and IIT Delhi. A reusable antimicrobial mask has been developed by a start-up (Nanosafesolutions) at IIT Delhi. Another start-up of IIT Delhi, ETEX has developed an affordable face mask, KAWACH.

- (b) At IIT Kharagpur, researchers are designing and developing rapid diagnostic kits, real-time PCR machines, bodysuits for patients, and hazmat suits with purified and cooled air circulation for medical professionals. IIT Bombay has developed,

Table 4 Roles visualized for various actors in Post-COVID-19

Actor	Role to be played
Head of the state Government	Provide strong support to industry Initiate labor reforms for enhancing ease-of-doing-business Offer suitable tax incentives for industries Introduce more poverty alleviation measures Provide physical and digital infrastructure at the village level Invest in a skill development programme Provide boost to Make-in-India initiative Facilitate Industry 4.0 which will also cater to specific needs of the state
Funding agencies	Provide finance at attractive terms but with a strong monitoring system Work closely with Government and other actors Install mechanisms to monitor the progress of projects Liaison with foreign funding agencies to attract more funding
Industry associations	Conduct sensitization and awareness programmes Facilitate massive skilling Facilitate Policy on Industry 4.0 and its effective implementation Collate and disseminate best practices
Educational/technical institutes/research organizations	Do capacity building, train and educate on low-cost automation Innovate low-cost solution Develop indigenous designs for critical care and daily use of healthcare equipment. Design products which are needed by the medical and allied industry Help the agriculture sector to leverage automation Develop strong network of institutes with Institutes of National Importance acting as nodal institutes for rapid product development and dissemination of know-how
Manufacturing sector	Manufacture the product looking at the dynamic needs of the market Invest in the process, people and technology Promote continuous innovation Liaison with educational institutes and research organizations Make close coordination with policymakers Facilitate consolidation of a few very large players
Service sector	Liaison with educational institutes, research labs and government Work in tandem with the manufacturing sector Evolve digital solutions to facilitate seamless integration with manufacturing
NITI Aayog (This is policy think tank of government of India)	Provide Policy framework for revival of the manufacturing sector Give a thrust on self-reliance Offer incentives for the proper balance between Industry 4.0 and low-cost automation Promote good corporate governance Allocate a higher budget on healthcare and education Evolve short term/long term plans in consultations with stakeholders

“Safe”, an app for adherence of quarantine besides many AI-based applications for tracking and surveillance.

- (c) The DBT has approved 70 proposals for funding to develop safe and effective biomedical solutions to counter COVID-19. These proposals are related to devices, therapeutics, diagnostic kits, etc.
- (d) The CSIR had joined hands with the TATA Sons for deployment and widespread use of the facility for mass testing.
- (e) IIT Alumni council has taken a proactive approach and formed IIT C19 Task force to channelize the global IIT alumni. IIT Bombay alumni launched Test Bus for COVID-19 which will facilitate mobile collection of samples and reduce the time drastically.

- (f) NITs are working on about 150+ projects which include testing kits, sanitization kits, medical equipment/robots., apps, etc.

- (ii) These efforts are illustrative of the agility, flexibility, and responsiveness of India’s technical education system to rise to the challenges. This is also an indicator of the tremendous talent pool that exists in the country.
- (iii) These institutes have responded overwhelmingly through their knowledge support, innovative devices, fund mobilization, and the production of relevant devices for dealing with the COVID-19.
- (iv) It is expected that the experience gained, and expertise developed need to be properly leveraged in coor-

dination with other actors to put Indian manufacturing at competitive levels.

- (v) The Indian economy was in not in good shape before the COVID-19; thus, it had limited scope to give stimulus to manufacturing. Indian may have to explore and attract foreign funding, given India's track record of technological innovations and huge technical pool. Foreign funds may come with liquidity. IMF loan will come with strings, and its own generation will lead to inflation.
- (vi) Indian corporates should try to become inward thinking and invest more in inhouse manufacturing. They can develop as an alternative manufacturing hub. Indian corporate need to invest judiciously in a mix of modern technology and traditional technology. They must be more transparent and need to develop a strong partnership with employees. Good management and bad management would make much difference for their future survival.
- (vii) The Indian service sector needs to build trust and deliver with a professional approach. It must collaborate with manufacturing and agriculture.
- (viii) The NITI Aayog will have to make very short-term plans which will be dovetailed into long term plans. It will have to work closely with industry and oversee the execution of these plans.

We see the emergence of very large corporations and extensive mergers and acquisitions to take place.

Discussion and Recommendations

The framework presented is a qualitative framework. It draws upon various competitive factors and environmental scanning through the lenses of PEST.

It seems clear from the COVID-19 pandemic scenario that the following are going to be the reality:

- (a) Work from home and virtual meetings of personnel,
- (b) Tight coupling of the cyber and physical world,
- (c) Supply chains and subsequent manufacturing activities will be driven by healthcare systems (Driver number D12 in Table 2)
- (d) Web technology is going to act as powerful enablers for (b) above

In this connection, it may be noted that most design principles and technologies that enable Industry 4.0 have already been used in practice, and they have been an active area of research for almost a decade (Ghobakhloo 2018; Javaid et al. 2020). We believe that COVID-19 will accelerate the active usage of Industry 4.0 in the Indian context.

The following points are to be noted:

- (i) As rightly observed by Deloitte (2016), Industry 4.0 will play a significant role in bringing automation at the forefront. Industry 4.0 is synergization of the physical and cyber world. Industry 4.0 also enables the use of a whole set of technologies such as
 - Additive manufacturing
 - Augmented reality/virtual reality and holography
 - Cloud computing, big data, and 5G
 - Robotics
 - Machine learning, AI and IoT
 - Social media
- (ii) It may be worth mentioning that it is possible to produce ventilators using 3-D printing technology, thereby reducing lead time drastically to meet the challenging deadlines posed by COVID-19.
- (iii) The above technologies are to be leveraged by Indian Manufacturing looking at the following factors
 - Low-cost automation
 - Use of quality and trained workforce
- (iv) In post-COVID-19, all influential countries will have to decide for a mix of conventional manufacturing facilities, the automated special purpose and industry 4.0. They cannot afford to bypass the traditional base of manufacturing.
- (v) Indian stands to leverage a considerable opportunity for enhancing its manufacturing base. Many of the drivers required for global manufacturing competitiveness are in India's favor. These drives are: Talent, Cost competitiveness, Workforce productivity, Supplier network
- (vi) One perspective is to an increased level of automation and implementation of Industry 4.0, and another view is to have traditional manufacturing facilities that can ramp up its capacity for surge demand of products.
- (vii) COVID-19 has forced us to relook at the Government, corporate, and society. Corporate social responsibility represents a form of corporate self-regulation that integrates into the existing business model. In the manufacturing environment, corporates social responsibility mostly involves areas such as environmental and labor regulations. With Industry 4.0, robotics and industrial automation will heavily influence job opportunities; In India, we must look at low cost and people-oriented automation, which will drive the corporates to perform their socially responsible role.
- (viii) Department of Heavy Industries, Government of India under the program SAMARTH (Smart & Advanced Manufacturing and Rapid Transformation

Hub) initiative has set up four centres with an objective of enhancement of competitiveness of the Indian manufacturing sector. These centres are being set up to support the industry in the early adoption of Industry 4.0. These centres are located at IIT Delhi, IISC Bangalore, CMTI Bangalore, and C4i4 (Centre for Industry 4.0) Lab, Pune.

- (ix) Industry 4.0 encompasses the use of robotics, artificial intelligence, smart manufacturing, and increasing digitization. The government of India is taking several steps to increase awareness about Industry 4.0 as it would help boost the growth of manufacturing in the country. We feel that digitization and automation efforts will be accelerated due to COVID-19. The above four centres will facilitate the adoption of Industry 4.0 and next levels such as technology transfer and NPD
- (x) There is a need for developing country-specific, industry 4.0 model which fits into the countries strategic requirements, for example, for India. We visualize a very proactive role to be played by various agencies (as shown in Table 4) to enhance the competitive position. The challenge is to do every agency work in close coordination with others.

Future Research Implications

At this stage, the world is still grasping the magnitude of the damage done by COVID-19. The damage is multi-fold and is caused by a variety of factors (lock-down, stoppage of movement, closure of air traffic, and resources being diverted to take care of causalities). It may take some time before the actual extent of damage is ascertained. However, specific pointers may be spelled out for future research:

- (a) Future research will be guided by health care considerations. Manufacturing policies, and priorities will be motivated by health care. This calls for close interaction between various disciplines such as medicine, engineering, technology, public policy and health care, psychology and economics. It is heartening to note that educational institutes and research organizations have started working on such interdisciplinary projects. It will be interesting to study the impact of such projects on enhancing competitiveness.
- (b) Both hard and soft disciplines will be synergized to handle huge challenges in manufacturing. In the Indian context, it will be interesting to study how manufacturing will affect the agriculture and services sector and at the same time provide opportunities for enhancing the export market.
- (c) The development of a post-COVID-19 sustainable business model provides exciting opportunities for

competitiveness practice and research. COVID-19 scenarios have invigorated thinking on a holistic approach to competitiveness. It is envisaged that the dimensions of competitiveness will require rethinking. Research to evolve linkages among relevant process factors of competitiveness, vis-a-vis environmental, and financial factors provide an opportunity for in-depth studies (Momaya 2019; Financial Express 2020).

- (d) Divergent patterns of country and firm competitiveness in India indicate some potential areas of research at interfaces of strategy, competitiveness, international business, and public policy (Momaya 2019). India has been doing well on dimensions like ease-of-doing-business for enhancing its competitiveness. However, more empirical and longitudinal studies are needed to assess how these dimensions have translated in achieving manufacturing competitiveness if any.
- (e) Industry 4.0 may provide a good template for taking a proactive role in manufacturing. There will be a healthy mix of cyber and physical systems. Health-care solutions, for example, drone-based systems for drug administration may require innovative inputs from augmented/virtual reality. It will be worthwhile to examine the mix of such cyber and physical systems leading to enhanced business performance.
- (f) It is vital to establish some causality due to some factors responsible for competitiveness. These factors may depend on the type of product and may be subject to government interventions. These interventions will be guided by societal expectations and available resources, especially post-COVID-19.
- (g) As a post-COVID-19 relief package for assistance, the Ministry of Micro and Small Enterprises (Ministry of Micro, Small & Medium Enterprise 2020) has announced the Lean Manufacturing Competitiveness Scheme (LMCS). Under this scheme, the MSME (micro, small and medium enterprises) will be assisted in reducing their manufacturing costs, through proper people management, better space utilization, improved process flows, reduced lead time, etc. LMCS is expected to improve quality of products with lowers costs, which are essential for competing in national and international markets. The larger enterprises in India have been adopting LMCS to remain competitive, but MSMEs have generally stayed away from such programmes. LMCS has been approved as a pilot project in 100 Mini Clusters for implementation. The objective is to enhance the manufacturing competitiveness of the MSME Sector. It will be interesting to do an impact study of such packages.
- (h) COVID-19 has underlined the failure of huge supply chains. It has also emphasized the need for localized solutions keeping in view a huge domestic market. It

will be interesting to study how higher self-reliance can be achieved for sustainable manufacturing. Various connotations related to self-reliance need to be examined. Currently, self-reliance is taken in a myopic sense and may appear to be contrary to the notion of globalization. COVID-19 has offered an opportunity to relook at these notions. The complex interplay of self-reliance with globalization needs to be explored. Such exploration may motivate interdisciplinary studies.

- (i) Competition Commission of India (CCI) has allowed the companies to make agreements with each other to collectively work in increasing efficiency of production, supply, distribution, storage, acquisition, etc. This will enable companies to go for collaborations. CCI approval will also help Indian organizations to cope with significant changes in supply and demand patterns arising out of the extraordinary situation caused by COVID-19. Though there is no empirical evidence to suggest that collaborations improve competitiveness, it is expected that collaboration will act as a strong enabler for sharing know-how and good practices. More empirical, product-specific studies are needed.
- (j) We visualize that there will be a variety of options coming up for Indian companies.

- (i) Some of the companies may merge with companies from abroad and vice versa.
- (ii) Some of the companies may be acquired by companies from abroad and vice versa.
- (iii) Some companies will emerge as an engineering, R&D service provider, or contract manufacturer.
- (iv) Some companies (for example, Public sector undertakings such as Bharat Heavy Electricals Limited (BHEL), Bharat Sanchar Nigam Limited (BSNL), etc.) may offer industrial land for setting up manufacturing bases in the country

It will not be just one partnership or collaboration that Indian companies will be looking at. There will be multiple partnerships that can be with different business models depending on the expectations of the prospective partners (both from India and abroad). The research will be required to explore mechanisms to facilitate such partnerships and look at the possible business performance measures to assess the effectiveness of such partnerships. Some theoretical constructs will be required to evaluate linkages between enabling mechanisms, performance measures, and competitiveness at the firm level.

- (k) Lockdown and its partial opening in phases have also sensitized policy-makers towards the condition of the

labor force. It will be interesting to define and examine the role and working conditions of workers in the manufacturing sector. There is a challenge to leverage the huge labor force and leverage opportunities for automation coming via Industry 4.0. Halder et al. (Halder et al. 2016) have examined the potential for export competitiveness in select cases. Learning from such studies needs to be mapped into Industry 4.0 vis-à-vis the role of labor productivity, flexibility, and its impact on competitiveness.

- (l) To understand, second-order and third-order effects and effects due to delay, system dynamic based framework will provide an opportunity to visualize various policy scenarios and their policy implications which will guide investment in thrust areas of manufacturing. For example, it may be worth developing various scenarios and asking various “What if “questions: What will be the impact of delay of raw material supplies on the production of ventilators? What will be the effect of incentives on this sector? What will happen if the mix of labor and automation is changed?

Concluding Remarks

COVID-19 has resulted in disruptions all over the globe. Indian Manufacturing is no exception to this. However, COVID-19 has also offered a new set of opportunities. Medical products and allied manufacturing are going to be very important.

Given the disruption which has happened globally in the supply chain in the manufacturing setups, a lot of global companies are looking to diversify their manufacturing basis. This is an ideal opportunity because India presents a very strong option in terms of a strong legal system, a young population, and a growing economy.

The present paper has broadly sketched various drivers and subsequent suggestions for enhancing India's manufacturing competitiveness. Some directions for future research are also identified. This paper presents conceptual research, may not have the perspectives of all the stakeholders. At this stage, the present paper offers some insights into the forthcoming manufacturing scenario. It may be noted that: (a) Framework proposed in Fig. 1 is a tentative proposal. It is expected that it will set the stage for forthcoming research opportunities, (b) It is qualitative in the absence of numbers, and (c) also the post-COVID-19 scenario is still emerging.

Key Questions Reflecting Applicability in Real Life

1. Conceptualize how COVID-19 pandemic would change the competitiveness of traditional manufacturing base of India.
2. In post-COVID-19 pandemic, the role of Industry 4.0 would be prominent than conventional manufacturing or vice versa for Indian industry. Which view seems more meaningful from situations such as maximize net foreign exchange earnings?
3. Do Indian corporates have to invest judiciously in a mix of modern technology and traditional technology and imbibe the labor model of Chinese manufacturing firms as an alternative manufacturing hub? What can they learn from evolving India-Japan cooperative clusters (e.g. near Bengaluru, Chennai, Pune or Neemrana)?
4. What are the imperatives for developing country-specific, industry 4.0 model which fits into the country's strategic requirements to enhance competitiveness?
5. How does the given framework set the stage for manufacturing competitiveness in the post-COVID-19 world order for India?

Acknowledgements The authors are grateful to the reviewers and the Editor-in-Chief for their comments which have helped in improving the quality of the paper.

Funding Not applicable.

Availability of data and material (data transparency) Not applicable

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Code availability Not applicable.

References

- Ajitabh, A., & Momaya, K. (2004). Competitiveness of firms: Review of theory, frameworks and models. *Singapore Management Review*, 26(1), 45–61.
- Bhawsar, P., & Chattopadhyay, U. (2015). Competitiveness: Review, reflections and directions. *Global Business Review*, 16(4), 665–679.
- Dangayach, G. S., & Deshmukh, S. G. (2003). Evidence of manufacturing strategies in Indian industry: A survey. *International Journal of Production Economics*, 83(3), 279–298.
- Deloitte. (2016). Global manufacturing competitiveness index: report. London: Deloitte Touche Tohmatsu Limited. <https://www2.deloitte.com/global/en/pages/manufacturing/articles/global-manufacturing-competitiveness-index.html>. Accessed 27 Apr 2020.
- Deshmukh, S. G. (2016). Manufacturing Competitiveness: Research Opportunities. *International Journal of Global Business and Competitiveness*, 11(1), 1–6.
- Dewangan, Devendra Kumar, Rajat, Agrawal, & Vinay, Sharma. (2015). Enablers for Competitiveness of Indian Manufacturing Sector: An ISM-Fuzzy MICMAC Analysis. *Procedia—Social and Behavioral Sciences*, 189, 416–432.
- Financial Express. (2020). <https://www.financialexpress.com/industry/coronavirus-brings-business-competitors-on-one-table-cci-allow-s-firms-to-work-together/1933729/>. Accessed 27 Apr 2020.
- Fortune. (2020). <https://fortune.com/2020/02/21/fortune-1000-coronavirus-china-supply-chain-impact/on>. Accessed 27 Apr 2020.
- Ghobakhloo, M. (2018). The future of manufacturing industry: a strategic roadmap toward Industry 4.0. *Journal of Manufacturing Technology Management*, 29(6), 910–936.
- Halder, A., Rao, S. V. D. N., & Momaya, K. S. (2016). Can flexibility in corporate governance enhance international competitiveness? Evidence from knowledge-based industries in India. *Global Journal of Flexible Systems Management*, 17, 389–402.
- Haleem, A., Javaid, M., Vaishya, R., & Deshmukh, S. G. (2020). Areas of academic research with the impact of COVID-19. *The American Journal of Emergency Medicine*, 20, 12. <https://doi.org/10.1016/j.ajem.2020.04.022>.
- Invest India Statistics. (2020). <https://www.investindia.gov.in/sector/retail-e-commerce>. Accessed 10 May 2020.
- Javaid, M., Vaishya, R., Bahl, S., Suman, R., & Vaish, A. (2020). Industry 4.0 technologies and their applications in fighting COVID-19 pandemic. *Diabetes & Metabolic Syndrome: Clinical Research & Reviews*, 14(4), 419–422.
- Johnson, G., & Scholes, K. (1993). *Exploring corporate strategy*. Hemel Hempstead: Prentice-Hall.
- Ministry of Micro, Small & Medium Enterprise. (2020). Announcement. <http://www.dcsmse.gov.in/schemes/lean-manufact.htm>. Accessed 12 May 2020.
- Momaya, K. S. (2019). The past and the future of competitiveness research: A review in an emerging context of innovation and EMNEs. *International Journal of Global Business and Competitiveness*, 14, 1–10.
- Momaya, K. S., & Anuprita, A. (2006). Glimpse of global competitiveness scenario of manufacturing: Opportunities for India in auto components industry. *Journal of Science & Engineering Research*, 13(1–2), 121–127.
- Narayana, M. R. (2014). Growth effects of industrial clusters: Evidence and implications for India. *South Asia Economic Journal*, 15(1), 71–92.
- National Policy for Skill Development & Entrepreneurship. (2015). *Ministry of Small-Scale Enterprises and Entrepreneurship*. Delhi: Government of India.
- Pratheesh, J. T., & Arumugasamy, G. (2020). Impact of Corona virus in Indian economy and banking sector-an overview. *Studies in Indian Place Names*, 40(18), 2090–2101.
- Rele, S. (2020). Emerging outbreaks and epidemic threats: The practicality and limitations in the development and manufacturing of treatments for Coronavirus (COVID-19). *Polymorphism*, 4, 45–52.
- Singh, R. K., Garg, S., & Deshmukh, S. G. (2007). Strategy development for competitiveness: A study on Indian auto component sector. *International Journal of Productivity & Performance Management*, 56(4), 284–307.
- Statista. (2020). <https://www.statista.com/statistics/270439/china-s-share-of-global-gross-domestic-product-gdp/>. Accessed 27 Apr 2020.
- Ward, D., & Rivani E. (2005). An overview of strategy development models and the Ward-Rivani model, *Economics Working Papers, European school of Economics*, Milan (Italy). <https://econwp.ub.uni-muenchen.de/econ-wp/get/papers/0506/0506002.pdf>. Accessed 15 Apr 2020.

- WHO. (2020). Coronavirus disease (COVID-19) technical guidance: Essential resource planning. <https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/covid-19-critical-items>. Accessed 27 Apr 2020.
- WTO. (2020). Press release of 8 Apr 2020, https://www.wto.org/english/news_e/pres20_e/pr855_e.htm. Accessed 27 Apr 2020.

S. G. Deshmukh is a professor in the Mechanical Engineering Department of IIT Delhi. His areas of interests include manufacturing competitiveness, quality, and modeling. He has more than 30 years of teaching and research experience. He is on the editorial board of several international journals. He is a member of ISME, IIIE, ASI, and QCFL.

Abid Haleem is a Professor of Mechanical Engineering, Jamia Millia Islamia (JMI), New Delhi, India. He has been founding Honorary Director, Internal Quality Assurance Cell, of the University. He headed the Mechanical Engineering Department and MBA (Evening) program at JMI. He has professional and life membership of IIIE, ISME, ISTE, GIFT, SCL, IICC, and ISC. He has published more than 140 papers and has three books to his credit. His latest book is, “*An update on Medical 3D Printing*” from Solubris. He has more than 33 years of teaching and research experience at graduate and higher level and has supervised/co-supervised more than 30 doctoral students.