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Significance of digital technology in manufacturing sectors: Examination of key factors during Covid-19

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ABSTRACT

The Covid-19 pandemic has been the center of human existential chaos throughout the world, which also has affected the manufacturer in an extraordinary and unexpected way. With the decline in demand, supply, and workforce the industries are driven into the gloom. The concerned research objective is to explore the factors which impact manufacturing throughout the world during the epidemic of Covid-19. Further, it delineates the usage of advanced digital technologies like artificial intelligence (AI), big data analytics (BDA), and internet of things (IoT) to bring on solutions/approaches to evolving to pandemic-constrained manufacturing. An overall of twelve key factors is determined from extensive literature reviews which are categorized into challenges and solutions. Here, ISM methodology has been used to establish the interrelationship among identified twelve challenges and solutions. Further, MICMAC analysis has categorized them according to their driving and dependence power. The consequences display the absence of autonomous factors whilst efficient supply chain, centralized decision making, product diversification, and JIT along with revenue generation turn out to be significant dependant factors. The facilitators like digital technologies are the pre-cursors to the ultimate solution of revenue generation and termed preliminary solutions. The outcomes of this research will suggest eventual policy recommendations for industry leaders to progress manufacturing within Covid-19 constraints. It will offer a sturdy base for manufacturers around the world to tune to the new digital transformation of the production scenario.

1. Introduction

The novel corona virus pandemic hit manufacturers in an extraordinary and unexpected way. It is a primary fact in cutting-edge manufacturing that demand, supply, and personnel availability have been influenced by means of this pandemic globally at an identical time (Alimadadi et al., 1152). The advanced and growing economies have confronted this one as the biggest macroeconomic shock over the last hundred years (Hevia & Neumeyer, 2020). It has led to chaos throughout the world. All sectors and dimensions that encompass humans are directly under the threat of this deadly virus (Moser et al., 2013). The grim impact has mesmerized the world and amidst a sunken glimpse of hope, the shock has been univocal (Dev & Sengupta, 2020a). The present scenario of the industrial sector is also critical. The ongoing lockdown has put a whole lot of stress on the manufacturing industry to increase their sales, which contributes nearly 20% of the GDP. All sections of livelihood are pushed under pressure and millions of jobs are lost (Cavallo and Forman, 2020a). Businesses-small or big are losing their momentum with turbulence in economic stability and sustenance has become the ultimate dictating factor of survival (Bartik et al., 2020a).

The worldwide FDI inflows sharply declined in the energy, automotive, and airlines industries because of corona virus outbreak (Bickenbach & Liu, 2020).The unavailability of raw material is the key challenge for the automobile, chemical, electronics, and aircraft manufacturing sectors during this pandemic (Gupta et al, 2020). Due to supply chain disruption, the electronics sectors including smart phones has paused their new product development and also have squeezed their production quantities (Ivanov & Dolgui, 2020). Due to the severe effect of Covid-19 in Europe, the factories of Volkswagen and Daimler have seized their production operations temporarily for the safety of manpower (Peto et al., 2020). The Covid-19 epidemic has forced some manufacturers for shifting their manufacturing units from severely affected locations to other less affected locations. Recently, Samsung Electronics has started some of its component manufacturing industries in Vietnam after a severe attack of corona virus in South Korea and

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Apple has started its iphone- 11 factory in India (Panigrahi et al., 2020) due to the better amicable situation as compared to China.

The Covid-19 has a grim impact on the social, economic, and environmental factors (the pillars of sustainability). Apart from the health crisis, the restrictions on economic activities imposed by social distancing/lockdowns and an external front with collapsing exports, dwindling remittances, and tightening international credit conditions are unanimously responsible for economic instability throughout the world (Hevia & Neumeyer, 2020). Manufacturing plants and factories need to embrace automation to stay relevant in the long run. Industry 4.0 and smart factory production, as well as the development of IoT technologies, will determine the manufacturing sector's future. Digital technology-driven machines add a sizable cost to the producing technique as they allow the automation of tasks, enhance manufacturing efficiency, and bring system interaction toward human interaction ((Mantelero, 2018), (Duan et al., 2019)).AI marketplace within the production enterprise record covers the size, trends, and industry analysis. Production planning, quality control, preventive maintenance, and machine inspection are some of the applications which are served by AI in today's era. A digital twin technology can be employed at numerous phases of the manufacturing process. To begin, a digital twin enables real-time monitoring of a manufacturing component, asset, system, or process (Bao et al., 2019).

Further, to tackle challenges set by the corona virus, the internet of things (IoT) can be implemented in a plug-and-play mode to combat economic downturn, ensure employee safety and security. IoT can aid the transit manufacturing process in several ways, such as tackling manpower, machine-condition-monitoring, and tracking products. Economically, IoT reduces cost, enhances diagnosis, helps make effective control, and superior treatment with reduced chances of mistakes (Singh et al., 2020). Big data can facilitate the automation process with fast processing and results to cater to the needs of the world through the establishment of a highly connected digital ecosystem (Alimadadi et al., 2020). The analytics gives accurate responses to large-scale data using a AI and deep learning systems. AI is getting empowered with the upward push of remarkable computing strength and huge statistics technologies (Duan et al., 2019). For example, timely and accurate diagnosis of Covid-19 is extracted through radiological features by the application of AI (Ting et al., 2020a). It also detects the disease through the help of neural networks (Allam and Jones, 2020a). Effective cybersecurity and data privacy are critical to the success of these new corporate operating models. To secure core business, a rapid and sustainable approach to addressing the principles of cyber hygiene is required (Corallo et al., 2020). Failure to do so will have a detrimental impact on consumer and institutional confidence, as well as fundamentally impair future trading capabilities and market position. Blockchain technology has been predicted as a disruptive technology that will play a significant role in managing, controlling, and, most importantly, protecting IoT devices by the industry and research community (Rane & Narvel, 2021)The blockchain's decentralized, autonomous, and trust qualities make it a perfect component for becoming a foundational component of IoT solutions. Enterprises using IoT technologies were among the first to use blockchain technology. IoT solutions can enable safe transactions between devices in an IoT network by leveraging block chain which further can retain an undeniable record of the history of IoT smart devices (Ko et al., 2018). As it does not exist in a single location, the blockchain ledger is tamper-proof and cannot be changed by malevolent parties. All of these skills are required to enable IoT compliance and regulatory requirements. . Blockchain technology is now being actively researched as it has the potential to be a useful tool in the global arena in a variety of economic and business domains (Tijan et al., 2019). The benefits of a distributed registry, such as the lack of a participant hierarchy, the ability to conduct transactions with protected personal data, and the high adaptability to various processes—from insurance operations to tracking the supply chain of goods—make this technology and solutions based on it more than relevant (Ghobakhloo, 2018). Companies' experience confirms their ability to optimize procedures and create less expensive alternatives to existing systems (Karpenko et al., 2019). The conditions, nature, and outcomes of global economic development are inextricably linked to technical advancements and scientific progress at all levels, from individual industries to national economies, influencing billions of people worldwide. The processes of "digitalization," the penetration of new technologies, and the principles of completing both routine and innovative tasks based on the Internet in areas such as retail, housing and car rental, workspace organization (cloud solutions, etc.) are becoming increasingly popular, and they have already made and are continuing to make significant changes to traditional social relations systems. The methodological foundation of work is a set of scientific knowledge methods in the form of general scientific and special research procedures. The following research methods were employed to attain the defined aim and complete the tasks: critical analysis, scientific abstraction, and generalization of modern theoretical studies' scientific experience; analysis and synthesis, induction and deduction, system analysis, and expert method. The blockchain's constant and unchanging, permanent nature allows, among other things, to use the blockchain as a bank, "storing" data in it, owing to the presence of tens of thousands of computer nodes on the network (to break and compromise with it, theoretically, with computing power would be unthinkable). Many retail chains will be able to incorporate ready-made blockchain solutions into their delivery processes in the future, enhancing customer confidence while cutting expenses associated with the usage of a relatively inefficient paper accounting system. Using a single personnel database on the blockchain, which will be cryptographically protected, processes such as job search and hiring may be substantially simplified and made more transparent.

The Covid-19 data collected in the form of epidemiological data, clinical data, or genetic data are managed and processed through AI, machine learning, and deep learning to find solutions to combat Covid-19 such as prevention, diagnosis, therapeutics, and hospital operation (Alimadadi et al., 1152). To sum up the benefits of digital technology as a savior to Covid-19 are significant in multiple ways. It can help plan the activities and provide a better experience in healthcare sectors and industries without imposing risks to workers (Javaid et al., 2020). The smart supply chain can be beneficial to provide service in time especially in the healthcare and industrial domain (Ting et al., 2020a). The issue of training can be accomplished by virtual reality and it helps perform daily life work during the lockdown. Digital technology is also useful for risk assessment of demand trends, innovations, and product diversification (Simpson et al., 2017).

Many recent pieces of research have focused on the importance of digital technologies to solve the problems of social, economic, and environmental crisis due to Covid-19 and its impacts, but none of them have chalked out the model to revive the manufacturing industries from this precarious situation. This gap is addressed in the research which intends to develop a model to delineate the clogged channels of revenue generation within the organization due to Covid-19 impacts. It may be considered as a survival strategy as the model attempts to address the crisis of 4M's (Men, Material, Machine, and Money) and constraints like transportation during the pandemic and elucidates a pathway to create revenue for the best interest of the organization. Thus, the research addresses the following research questions:

RQ1. To identify the factors which may influence the revenue generation in industries during/after the Covid-19 pandemic.(?)

RQ2. To develop the interrelationship among the recommended factors. (?)

RQ3. To determine the driving and dependence power of the identified factors. (?)

In this study, twelve factors were identified influencing revenue generation in industries during covid pandemic times with the help of literature review and experts' opinions (RQ1). For RQ2, authors have

used the robust Interpretive Structural Modelling (ISM) technique to develop the relationship among factors that influences a particular issue or a problem. To address RQ3, MICMAC (Matriced' Impacts Croise's Multiplication Appliqué an un Classement) analysis is done to find driving and dependence power of the influential factors. The outcomes of ISM are utilized as an input to MICMAC investigation. Further, this study provides insights to the industries around the world to recover from pandemic affected precarious situation and focuses on providing a prerequisite to strategy formulation through the ISM model. The model acts as a probable tool for pandemic-hit industries to recapacitate themselves with a new strategy to bring about revenue generation for the smooth functioning of the industrial world.

The paper has been demonstrated in the following way; section 2 highlights the literature of past researchers about the challenges and solutions factors associated with the manufacturing sector during Covid-19; section 3 determines the driving and dependent powers of identified key factors with proposed ISM methodology; section 4 represents the insights of the results of ISM framework; section 5 suggests eventual policy recommendations to the decision-maker with practical implications and finally section 6 concludes with future scope of the research.

2. Theoretical background

The literature that is prevalent in digital technology and covid domain has been searched and relevant articles pertaining to use of digital technology has been identified. The searches were conducted in Google Scholar, Web of Science, and Scopus to identify the relevant content. A set of predetermined rules provides the basis for including or excluding certain studies (Vargo et al., 2021).

The inclusion criteria were the following:

(i) any primary research will mainly focus on empirical and literature reviews
(ii) the research aimed at technology use specifically using Covid-19 pandemic.
(iii) the search was limited to English articles only
(iv) the time-restriction is from the first outbreak of the virus in late 2019 until now, with most research focusing on 2020.

After the keyword search in databases, references of relevant articles were searched manually for relevant studies. Once a group of potential studies has been identified, we screened each of these articles to determine their relevance (Popay et al., 2006). The following paragraphs highlight the relevant literature for this research.

The SARS-CoV-2 unfolds on more than 220 nations infecting around 186,071,922 individuals, which also has affected the manufacturers extraordinarily and unexpectedly. With the decline in demand, supply, and workforce, the industries are driven into the gloom. Moreover, lack of resources i.e. 4M's (Men, material, machines, and money) and transportation constraints have attributed to lackluster operational performance of the firms (Gray, 2020). Availability of buyers is a motive force for any production (Sarkis et al., 2020a). On the contrary, under prevalent circumstances, its unavailability is an economic and practical demotivater for any industry (Ivanov, 2020a). Dysfunction of global supply chains and incapability of local ones have disrupted the backbone of the global economy (Ranney et al., 2020a). Under these catastrophic circumstances, the industrial sector has been in search of new tools, techniques, and methods to challenge the existing novel problems (Ivanov & Das, 2020). To a certain extent, the industrial chapter of the world has inclined itself to technological advancements to propel the production/services to mankind overcoming the Covid-19 impacts (Allam and Jones, 2020b).

For manufacturers, the digital landscape is continuously changing. Change is spread across the supply chain by quickly changing consumer expectations, networked gadgets, and technological advancements in adjoining industries (Ghobakhloo, 2018). Digital transformation in manufacturing is already having an impact on organizations, their suppliers, customers, and other third parties. Digital transformation has the potential to completely transform businesses. Real-time insights, for example, can aid in the monitoring, resolution, and even prediction of problems to optimize machinery lifecycles (Paschou et al., 2017). This ensures that operations are error-free and that no disruptions occur. Because innovation breeds innovation, a digital transformation plan lays the groundwork for a comprehensive optimization approach.

Industry 4.0 refers to a movement in which traditional manufacturing and industrial factories are combined with digital technology. The major goal of Industry 4.0, often known as "the fourth industrial revolution," is to automate manufacturing processes to the point where all activities are automated and controlled in real-time (Xing et al., 2021). One of the key technologies of Industry 4.0 is IoT. The Internet of Things (IoT) is a network of interconnected physical things that communicate using calculated data, as well as data from outside sources. Manufacturers may gain from additional functions, services, and benefits as a result of it. Operations, asset management, and personnel management are the most common IoT use cases (West et al., 2021). Manufacturers can, for example, implement preventative maintenance programs with real-time monitoring, increase energy efficiency and working conditions through smart air management, risk management, worker productivity, and other methods (Xia et al., 2020). A digital twin technology can be employed at numerous phases of the manufacturing process. To begin, a digital twin enables real-time monitoring of a manufacturing component, asset, system, or process (Bao et al., 2019). These improved monitoring capabilities provide a more in-depth understanding of what is happening on your production lines and throughout the manufacturing process (Abdulmotaleb, 2018). At the component level, the focus is on a single, crucial component in the manufacturing process. Creating a digital twin of a single piece of equipment within a production line at the asset level. At the system level, a digital twin can be used to track and enhance an entire production line. At the process level, everything from product and process design to development to manufacturing and production is examined (He & Bai, 2021).

However, effective cybersecurity and data privacy are critical to the success of these new corporate operating models. To secure core business, a rapid and sustainable approach to addressing the principles of cyber hygiene is required (Corallo et al., 2020). Failure to do so will have a detrimental impact on consumer and institutional confidence, as well as fundamentally impair future trading capabilities and market position. Smaller manufacturers are more likely to be attacked than big manufacturers because hackers frequently see them as easy entry points into larger manufacturing chains (Zarreh et al., 2018). Smaller manufacturers are more likely to be attacked than big manufacturers because hackers frequently see them as easy entry points into larger manufacturing chains. Blockchain technology might be viewed as the missing link in resolving IoT security, privacy, and dependability concerns. It can be used to track billions of connected devices, execute transactions and coordinate across devices, and provide significant cost savings to IoT industry makers (Zhang & Chen, 2020). This decentralized method would eliminate single points of failure, resulting in a more durable ecosystem on which gadgets might run. Blockchains' encryption algorithms would make consumer data more private.

Industry 4.0 is up to the task (Naudé, 2020) and its three major digital technologies are apt to meet the challenge to overcome the impacts of the pandemic: internet of things, big data analytics, and artificial intelligence (Ting et al., 2020b). Table-1 defines the key factors, their definitions, and descriptions extracted from the literature review. The table showcases each factor, its code, and category followed by the description and associated references. The category column classifies the factors into challenges and solutions to this pandemic Covid-19. It demarcates the significance of digital technology as well as confirms the challenges in manufacturing in the Covid-19 pandemic.

2.1. Factors identified from literature review

12 key factors were identified that influence the revenue generation in manufacturing industries in the Covid-19 pandemic circumstances. This section is a brief overview of the various challenges that pose a threat to an industries' survival and the various solutions to tackle the posed challenges. The challenges and solutions are highlighted in Table 1 "Category" column.

F-1: Significance of AI [SAI]

The digital technologies of IoT, BDA, and AI can be applied to tackle major clinical and industrial problems during and after the Covid-19. Manufacturing and supply networks worldwide are undergoing a digital transformation under the umbrella of smart manufacturing and industry 4.0 (Wuest et al., 2020). AI can mitigate the adversities and strengthen the resiliency and preparedness of manufacturing and networks in the future. AI models require historical data, a skilled workforce, quality data, and lean process solutions. So, both lean and AI-inspired digital transformation may complement each other (Surya & Yarlagadda, 2020).

F-2: Lack of Resources [LOR]

The lack of raw materials is evident due to "lockdown" in various parts of the world. The entire supply chain is also disrupted with no adequate workforce and demand/needs as to previous/normal conditions (Ranney et al., 2020b). The machinery under breakdown situations can neither be repaired nor replaced with new ones. Such a crisis will hamper manufacturing/production and the industries might work with constraints or completely shut down of facilities may occur. This further aggravates the employment and humans' economic sustainability crisis towards the peak. From medical equipment to medicines and other products cannot meet the demand under such circumstances (Bong et al., 2020).

F-3: Centralized decision making: [CDM]

The managerial decision-making is under stress at top levels with uncertain results as the human race is facing the pandemic, the novel Covid-19. The policy breakdown and random exploration of decisions under different hypothetical assumptions of the crisis have created chaos in the world. In such a critical situation, decision-making has to reshape itself as a transformation to the next level of existence and aptly centralizing to empowering small units to improvise effective decisions as per convenience without jeopardizing the productivity and economy as far as possible (Bartik et al., 2020b).

F-4: Product Diversification and Just-in-Time: [PDJIT]

The corona virus outbreak exposes the vulnerability of overreliance on just-in-time (JIT) and Lean delivery systems. As alternatives, smarter logistics systems including reverse logistics for secondary materials and waste products enabled by IoT technologies are well expected. The trend towards "glocalization"- localization of the global network and consideration of both global and local aspects jointly can be a motivating prospect. Lean, known as a "warrior philosophy" can help to improve work life with limited resources (Sarkis et al., 2020b). In Covid-19 economy, speculations are strong that some features of lean philosophy can be an added advantage as tools to deploy the resurrection of the world economy back to normal. Product diversification, in specific, can be a major attribute/driver of the future scope of manufacturing. Product differentiation leads to high variety-high volume products to meet the ends. Lean, thus again, can prove as a "game-changer" in the manufacturing world (Ivanov, 2020b).

F-5: Revenue Generation: [RG]

The revenues have become depleted at all levels from business to governance due to the effects of Covid-19. Under these circumstances, revenue generation is a key challenge for global leaders to entrepreneurs. Outsourcing or moonlighting is not the available options for preserving revenue. As small businesses, private practice leaders have to apply for federal loans and grants from international organizations. Withholding shareholders' bonus payments or basic pay reduction among the staffs, increasing bank credit lines and malpractice insurance deferral are other maneuvers to generate revenue along with cost reduction, eliminating incentives to employees to work over-time and internal moonlighting with few others (Cavallo and Forman, 2020b).

F-6: Significance of IoT [SIoT]

Industrial IoT empowers modern companies to adopt new data-driven strategies and handle the global competitive pressure more easily. The adoption of IoT, especially in Covid times, enables the transition of traditional human-labor-based manufacturing systems into modern digitized ones, generating significant economic opportunities through industrial reshaping (Mourtzis et al., 2016). The smart environment created through a network of interconnected objects significantly improves sensing, identification, processing, communication, and actuation capabilities. With IoT, the manufacturing sector is open to create whole new business and market opportunities. IoT enabled manufacturing (eg. German Industry 4.0, factory of future EU, and Made in China, 2025) is such an effort, which will have a high impact in the global economy (Yang et al., 2016).

F-7: Efficient Supply Chains: [ESC]

The global supply chains are increasingly complex, making a data-driven approach. The data-driven SCM provides visibility from end to end for monitoring the flow of information, services, and goods from procurement to manufacturing and delivery to the end consumer (Haeri et al., 2020). The efficient supply chains, which are a potential solution to the pandemic-hit manufacturing industries can help build better collaboration, improved quality control, higher efficiency rate, keeping up with the demand, shipping optimization, reduced overhead costs, improved risk mitigation, and improved cash flow, all of which are pre-cursors to revenue generation (Guan et al., 2020).

F-8: Covid-19: [COVID]

The industrial workforce is knowledgeable about the technologies and how to apply them to solve real-world problems. But since the advent of Covid-19, the workforce has been pushed into an uncertain territory of fear and unawareness about how to tackle the pandemic situation and how changes in the workplaces are to be addressed (Eikhof, 2020). The critical thinking and idea generation techniques have to evolve and transform to the next level to acclimatize to the situation. The problem is of human fundamental existence in the planet and to move ahead with the challenge, awareness and cross-functional teamwork are inevitable armors to the workforce (Cai & Luo, 2020).

F-9: Significance of Big Data [SBDA]

The sheer volume and complexity of large data sets and the number of specific tools, techniques, and best practices for working with them have led to the maturation of the field of data science and big data analytics in manufacturing (Al-Abassi et al., 2020). In the industries, big data can include data collected at every stage of production, including data from machines, devices, and operators. The application or significance of big data as a solution to improve revenue generation in post-covid industries include predictive maintenance, predictive

Table 1
Codes, definitions, and descriptions of factors extracted from literature review.

Abbreviation	Code	Factors identified	Category	Definition	Description From Literature	References
SAI	F1	Significance of AI	Solution	AI is the ability of a computer or a robot controlled by a computer to do tasks that are usually done by humans because they require human intelligence and discernment. Although there are no AIs that can perform the wide variety of tasks an ordinary human can do, some AIs can match humans in specific tasks.	AI predicts the slow positive impact in manufacturing during Covid-19 pandemic. In this state of affairs, the market is expected to enjoy a mild decline of around average (2.5%) in 2020 and a relatively fast restoration from 2021 onwards.AI imparts enormous solutions to manufacturing industries	(Alimadadi et al., 2020); (Ting et al., 2020a)
LOR	F2	Lack of Resources	Challenge	Money, material, machine, and manpower are the four Ms, the traditional framework for viewing the resources available to a business, which can be useful when designing a business plan. Failure to supply the resources required by a business often results in organizational failure.	A crisis of 4Ms (men, material, machine, money) will hamper manufacturing/ production and the industries might work with constraints or completely shut down of facilities may occur. From medical equipment to medicines and other products cannot meet the demand under such circumstances.	(Hevia & Neumeyer, 2020); (Ranney et al., 2020a)
CDM	F3	Centralized Decision Making	Solution	Centralization refers to a setup in which the decision-making powers are concentrated in a few leaders at the top of the organizational structure. Decisions are made at the top and communicated to lower-level managers for implementation.	The managerial decision-making is under stress at top levels with uncertain results as the human race is facing the pandemic, the novel Covid-19. In such a critical situation, decision-making has to reshape itself as a transformation to the next level of existence with centralizing decision-making and empowering small units to improvise aptly as per convenience without jeopardizing the productivity and economy as far as possible.	Bartik et al. (2020a)
PDJIT	F4	Product Diversification and Just-in-Time	Solution	Product diversification is a strategy employed by a company to increase profitability. They show how well a company utilizes its assets to produce profit and achieve higher sales volume from new products. Diversification can occur at the business level or at the corporate level. The just-in-time (JIT) inventory system is a management strategy that minimizes inventory and increases efficiency.	In Covid-19 economy, speculations are strong that some features of lean philosophy can be an added advantage as tools to deploy the resurrection of the world economy back to normal. Product diversification, in specific, can be a major attribute/driver of the future scope of manufacturing. Product differentiation leads to high variety-high volume products to meet the ends.	Ivanov (2020a)
RG	F5	Revenue Generation	Solution	Revenue generation is one of the most important activities any business can engage in. It is defined as a process by which a company plans how to market and sell its products or services, to generate income, establishing the business goals for the financial year.	The revenues have become depleted at all levels from business to governance due to the effects of Covid-19. Under these circumstances, revenue generation is a key challenge for global leaders to entrepreneurs. Outsourcing or moonlighting is not the available options for preserving revenue.	Cavallo and Forman (2020a)
SIoT	F6	Significance of Internet of Things	Solution	The IoT describes the network of physical objects—"things"—that are embedded with sensors, software, and other technologies to connect and exchange data with other devices and systems over the internet.	Manufacturing industries can leverage IoT technology to track raw materials, inventory, and finished goods in the logistic process. Such remote-tracking can reduce the need for physical inspection and manual data recording. The embedded tags transfer real-time data to clouds through middleware, such as temperature, vibration, tampering, and location. Thus team can take proactive decisions to prevent damage and maintain the quality of products. IoT in Covid-19 is chargeable for decreasing the probabilities of mistakes, lesser expenses, superior diagnosis, effective manipulate, and superior treatment	Ting et al. (2020a)
ESC	F7	Efficient Supply Chains	Solution	An efficient supply chain makes the best use of its resources — financial, human, technological or physical. By doing so minimizes costs for materials and packaging and reduces time wastage.	A special case of SC risks has been established due to the epidemic outbreaks. Suppliers mapping, government initiative, and near-shoring are the key pillars of an efficient and resilient supply chain. Such disruption has affected Fortune 1000 companies severely owing to its global culture.	Ivanov (2020a)
COVID	F8	COVID-19	Challenge	The Covid-19 pandemic, also known as the corona virus pandemic, is an ongoing global pandemic of corona virus disease 2019 (Covid-19) caused by severe acute respiratory	1. The industrial workforce has enough knowledge of how to practice the technology to resolve real-global problems. But since the advent of Covid-	Simpson et al. (2017)

(*continued on next page*)

Table 1 (*continued*)

Abbreviation	Code	Factors identified	Category	Definition	Description From Literature	References
				syndrome coronavirus 2 (SARS-CoV-2). It is the cause of industrial wreckage throughout the world.	19, the workforce has been pushed into an uncertain territory of fear and unawareness about how to tackle the pandemic situation and how changes in the workplaces are to be addressed. The problem is of human fundamental existence in the planet and to move ahead with the challenge, awareness and cross-functional team work are inevitable armors to the workforce	
SBDA	F9	Significance of Big Data	Solution	Big data is a term that describes the large volume of data – both structured and unstructured – that inundates a business on a day-to-day basis. But it's not the amount of data that's important; Big data can be analyzed for insights that lead to better decisions and strategic business moves.	Global data during Covid-19 developed the facts by using Big data.The data is collected by means of mathematical modeling. To perceive geographical hotspots, create death prediction models, also providing probable estimates concerning the need for sorting out supplies, and decision-making among policymakers, fitness care providers, and key stakeholders. Big data plays a vital role in the early detection of Covid-19.	(Javaid et al., 2020); (Allam and Jones, 2020b); (XuPatrick and Zou, 2020)
TC	F10	Transportation Constraints	Challenge	Transport of goods by air, water, road or rail. The constraints would be: • the type of work and its bulk once packed • the means of transport existing between the starting point and the destination • the possible routes • the time you have to complete the operation • the presence or absence of a courier	The Covid-19 has created significant new challenges for transportation systems. Air freight is very limited which have serious repercussions on export and import losing economy rapidly. The lack of contributions of rail within the country has consequences of similar proportions. Major ship consignments are canceled, thereby lowering the economic prowess of the country further. Road transport- both local and national is also largely affected.	Ranney et al. (2020a)
UB	F11	Unavailability of Buyer	Challenge	A buyer is a person who is buying something or who intends to buy it. Unavailability of a buyer refers to the set of constraints which changes the buyer's psychology towards procuring a product.	Consumers are the buyers of the products of manufacturing. Due to Covid-19, the economic crisis and change of policies of governments throughout the world has resulted in less consumer demands and purchasing power has decreased significantly. The psychology of the consumer has also taken a drift.	Dev & Sengupta (2020a)
LOP	F12	Lack of Operational Performance	Challenge	Operational performance has become widely accepted as a critical success factor for companies across many industries. It is best described as the level at which all business units in an organization work together to achieve core business goals. Lack of operational performance indicates the gloomy future of the organization	Human resources use material, money, and machines to provide operational excellence. Due to Covid-19, a crisis is seen in all the four constraints of performance. Thus, both resources and transportation facilities lack to provide efficiency and effectiveness in operational performance.	Ivanov and Das (2020)

quality, anomaly detection, computer vision, tool life-cycle optimization, supply chain management, production forecasting, improving throughput and yield, work cell optimization, and product lifecycle management (Bragazzi et al., 2020).

F-10: Transportation Constraints: [TC]

Transportation of goods can be by air, water, road, and rail. The Covid-19 has created significant new challenges for transportation systems. Airfreight is very limited which have serious repercussions on export and import losing economy rapidly. The lack of contributions of rail within the country has consequences of similar proportions. Major ship consignments are canceled, thereby lowering the economic prowess of the country further. Road transport-both local and national is also largely affected. Transport being a strong pillar of a nation's economy, the Covid-19 has a devastating impact on the nation's overall stand in the world (Ho et al., 2020).

F-11: Unavailability of Buyers: [UB]

Consumers are the buyers of the products of manufacturing. Due to Covid-19, the economic crisis and change of policies of governments throughout the world have resulted in fewer consumer demands, and purchasing power has decreased significantly (Dev & Sengupta, 2020b). The psychology of the consumer has also taken a drift. So, the motive power of manufacturing companies to produce commodities is drying. This instability will cause turbulence in the industrial sector. Again, lean might be an answer for the industries to rescue them from the situation (Naeem, 2020).

F-12: Lack of Operational performance [LOP]

Manufacturing companies are struggling to achieve excellence in their operations in terms of improved quality, productivity, and reduced cost. The Covid-19 pandemic has further aggravated the lacklustre operational performance due to unavailability of personnel, the crisis in the workforces' mental, physical and social dimensions along with lack of resources (Arshad Ali et al., 2020). Lack of operational performance is one of the major concerns that need to be alleviated in manufacturing industries in this covid era. Enhancing operational performance includes improving different production activities to create high-quality products which lead to revenue generation and profit maximization (Belhadi

et al., 2021).

3. Research design

In this paper, the authors have followed a sequence of steps to fulfill the objectives. First, the key factors are identified through an extensive literature review and experts' opinions. Thereafter, the ISM-based model is formed to determine the relationship between the factors, and finally, MICMAC analysis is performed to categorize the factors. The framework of the research has been mentioned in Fig. 1.

3.1. Data collection

First, the authors delved into an exhaustive literature review to discover the factors that are beneficial to reinstate the revenue generation in the covid affected industrial paradigm. The authors searched the scientific databases such as Scopus and Web of Science with keywords like Covid-19, manufacturing performance, digital technology, and ISM. Second, abstracts of all the retrieved articles were screened to select the relevant studies for the concerned research. Third, a list of key factors that are pre-cursors to revenue generation in industries was prepared and sent to the experts for final evaluation. The experts used the five-point Likert Scale (0 for No influence; 1 for very low influence; 2 for low influence; 3 for high influence; 4 for very high influence) to eliminate the factors which possess low rating and no influence on revenue generation in industries (Singhal et al., 2019a). We had the privilege of talking to 15 experts from an online webinar interaction regarding the "Make in India" theme held at KIIT University, Bhubaneswar, Odisha during the Covid pandemic. They enlightened us with their opinions which formed the basis of our data (key factors) for the ISM model. Out of fifteen experts, nine from different industrial sectors like automobile, electronics, chemical, textile, and six from academia with minimum associate professor level have been chosen for the study. Selected industry experts are having vast experience in manufacturing, supply chain, quality control, project management, human resources, and R&D management field. Similarly, academia has been selected based on their research regarding disruptions in the supply chain, productivity management, quality improvement, and digital technology application field. The number of experts selected for this research is sufficient as ISM does not put a limit on the sample size of experts. Moreover, researchers in the past have also considered a similar sample size. Thus, the number of participation of experts for this study is adequate as per the views of past researchers ((Mangla et al., 2018); (Mishra et al., 2020)).

3.2. Interpretive Structural Modelling (ISM)

ISM is a methodology to identify and summarize relationships among different items which define an issue or problem. It is an interactive technique that uses the input of the experts in developing the interrelationships between the elements of a complex system ((Tripathy, Sahu, & Ray, 2013), (Diabat & Govindan, 2011)). The benefits of ISM lies in the requirement of fewer experts than other methods like the delphi method, structural equation modelling, and it gives a structured form as a model from the unstructured and unclear raw data. The significance of ISM methodology is to establish a well-established interrelationship between the different factors for an issue. ISM converts the unstructured and unclear model to a structured well-defined model (Chakraborty et al., 2019). It focuses on the direct and indirect relationship between the factors and represents a transparent view of the issue (Sushil, 2012). It also emphasizes the long-term and short-term focused factors of an issue (Tripathy et al., 2013). ISM combines the experts' opinion and their depth understanding in a best-organized way.

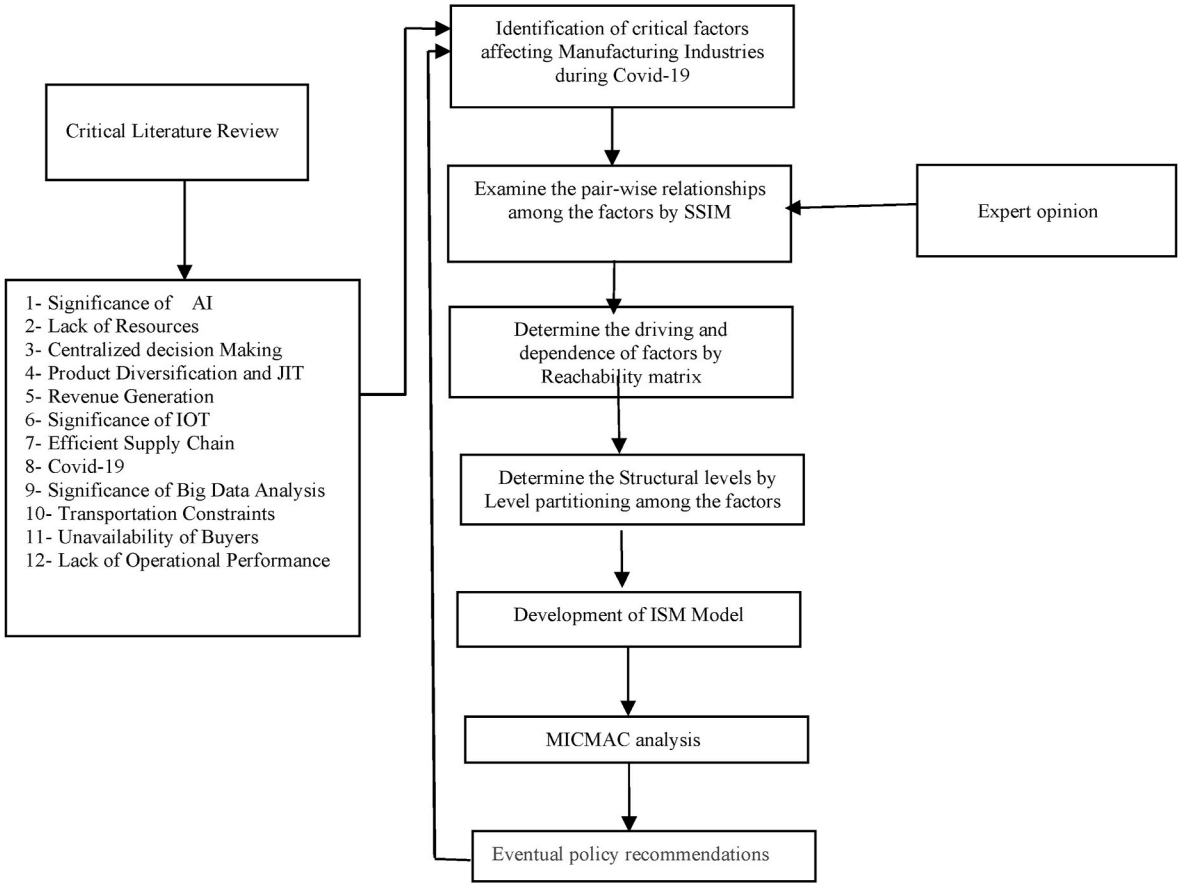

Fig. 1. Framework for significance of digital technology in manufacturing industries during Covid-19.

So, a fast managerial vision can be derived from this handy technique ((Thakkar et al., 2005), (Thakkar et al., 2007)). This research pinpoints the interdependencies of the factors affecting the manufacturing industries during Covid-19. Therefore ISM is a suitable tool for this purpose. The choice of the framework is suitable as this methodology provides a means, by which a group can impose an order on the complexity of the items. ISM offers a variety of advantages such as the experts' subjective judgments and their knowledge base is incorporated most systematically and provides ample opportunity for revision of judgments. Computational efforts involved are very less for objectives (items) ranging in ten to fifteen numbers and it can be used as a handy tool in real-life applications. But there are a few limitations to ISM such as it does not determine the intensity of relationships. Moreover, the results obtained through the ISM model may be influenced due to biased judgments of the experts, which can be alleviated by experts' experience and depth in giving unbiased opinions. So, ISM is a robust method for our research in identifying and building a model to describe the challenges and solutions to industries for revenue generation as a strategy to the post-covid era of industrial paradigm.

Table 2 illustrates the application of ISM of recent researchers during the decision-making process in different fields. The study conducted is the first of its kind where ISM methodology is used to provide solutions to the manufacturing sector during the Covid era. The problem is novel and hence out of the general literature available, this study is a pioneer work towards providing a set of solutions to industries affected with Covid-19 through ISM methodology. The above discussions have justified that ISM is an appropriate technique to build a reasoning link among the factors with driving powers and dependencies.

The procedure of ISM methodology is as follows. (1) Construction of structural self-interaction matrix (SSIM) using experts opinion from the identified factors; (2) Reachability matrix formation for determination of driving powers and dependencies of the identified factors; (3) Level partition of factors using reachability matrix; (4) Development of Interpretive Structural Model (ISM); (5) Finally classification of factors using MICMAC analysis into 4 segments like autonomous, dependant, linkage and driver based on their driving powers and dependencies.

3.2.1. Structural self-interaction matrix (SSIM)

A total of fifteen experts from academia and industry gave their valuable opinions which helped the authors to develop the contextual relationship among the factors. The SSIM has been developed after receiving the input of pairwise comparison between the factors. The nature of the relationship between two factors (x and y) is denoted by utilizing the following four symbols: (i) V, if x influences y (ii) A, if y influences x (iii) X, if x and y influence each other (iv) O, if x and y having no relationship. The SSIM matrix for key factors influencing manufacturing industries during Covid-19 is shown in Table 3 based on experts' opinions using the above four symbols. This SSIM is the prerequisite of the reachability matrix.

Table-2
Focus of ISM by recent researchers.

Resources	Objective
Bai and Ren (2020). (Bai & Ren, 2020)	Factors Influencing Enterprise Transformation
Xiaoxiao and Patrick (2020) (XuPatrick and Zou, 2020)	Factors affecting building energy performance
Ali et al. (2020). (Ali et al., 2020)	Barriers to software outsourcing partnership formation
Naimish and Debasis (2020). (Bhatt & Sarkar, 2020)	Risk factors for highway project performance
Mishra et al. (2020). (Mishra et al., 2020)	Key Success Factors of Indian Pharmaceutical Supply Chain
Singhal et al. (2019) (Singhal et al., 2019b)	Sustainability through remanufacturing of e-waste

3.2.2. Reachability matrix

The SS1M has been converted into a binary matrix by substituting V, A, X, O by 1 and 0 called the reachability matrix. The substitution of 1s and 0s are as per the following rules: (i) If the (x,y) position is symbolized by V in SSIM matrix, then (x,y) and (y,x) position in the reachability matrix will be 1 and 0; (ii) If the (x,y) position is symbolized by A in SSIM matrix, then (x,y) and (y,x) position in reachability matrix will be 0 and 1 respectively; (iii) If the (x,y) position is symbolized by X in SSIM matrix, then (x,y) and (y,x) position in reachability matrix will be 1 and 1 respectively; (iv) If the (x,y) position is symbolized by 0 in SSIM matrix, then (x,y) and (y,x) position in reachability matrix will be 0 and 0 respectively. Further, it also follows transitivity. Transitivity implies that if the first factor leads to the second factor and the second factor leads to the third factor, then the first factor leads to the third factor. The final reachability matrix is shown in Table 4. Furthermore, this reachability matrix shows the driving powers and dependence of each factor. In this study, factor 8 and factor 5 are showing maximum driving powers and dependence respectively. This driving power and dependence of each factor helps for MICMAC analysis as shown in Fig. 3.

3.2.3. Level partition

At step three, the reachability set and antecedent set of each factor has been calculated from the reachability matrix. The same factor and other factors influenced by a factor is known as reachability set whereas the same factor and other factors that are influencing to achieve that factor are known as antecedent set. Intersection set implies the common factor/factors between reachability set and antecedent set. Then level one will be decided when the reachability set, and intersection set having the same value. In this study, Factor 5 has the same value in reachability set, and intersection set. Therefore factor 5 is considered as level one and is placed at the top of the model as shown in Fig. 2. After getting the level one or top-level factor, it will be separated from other factors. Then other levels of factors will be identified in a similar way. The final ISM model will be carried out with the aid of using the identified level. Table 5 is showing the reachability set, antecedent set, intersection set, and level of all factors. Eight levels have been found in this study in which factor F5 is level 1 and F8 is level 8 respectively.

3.2.4. Formation of interpretive structural model (ISM)

Fig. 2 shows the ISM-based model which is formed by using a level partition table and digraph. The digraph represents the interdependence among the factors in terms of nodes and edges. The vertices or nodes and lines of edges from the final reachability matrix are generating the ISM model (Govindan et al., 2012). An arrow that points from x to y represents a relationship between factors x and y. The digraph is transformed finally to the ISM model after excluding the transitivities. The structural relationship among the key factors has been presented in the ISM model.

3.3. MICMAC analysis

The driving powers and dependence diagram is also known as MICMAC (Matriced'Impacts croises-multiplication appliqué an un Classement) analysis. The derived driving powers and dependence are the input for MICMAC analysis (Sivaprakasam et al., 2015). The identified key factors defined and described earlier are classified into four quadrants as shown in Fig. 3:(i)The first quadrant factors having low driving powers and low dependence are known as autonomous factors; (ii) The second quadrant factors having low driving powers and high dependence are called as dependent factors; (iii) The third quadrant factors having high driving powers and high dependence are termed as linkage factors; (iv) The fourth quadrant having high driving powers and low dependence is noted as a driver (Raj et al., 2008).

4. Results and discussion

This research seeks to investigate and establish a structural

Table 3
Structural self interaction matrix.

Factors	Notations	SAI	LOR	CDM	PDJIT	RG	SIOT	ESC	COVID	SBDA	TC	UB	LOP
Significance of AI	SAI		A	V	V	V	X	V	A	X	A	A	A
Lack of resources	LOR			V	V	V	V	V	A	V	O	V	V
Centralized decision making	CDM				V	V	A	O	A	A	A	A	A
Product diversification and JIT	PDJIT					V	A	A	A	A	A	A	A
Revenue generation	RG						A	A	A	A	A	A	A
Significance of IoT	SIOT							V	A	X	A	A	A
Efficient supply chain	ESC								A	A	A	A	A
Covid-19	COVID									V	V	V	V
Significance of big-data	SBDA										A	A	A
Transportation constraints	TC											V	V
Unavailability of buyer	UB												A
Lack of operational performance	LOP												

Table 4
Reachability matrix.

Factors	Notations	SAI	LOR	CDM	PDJIT	RG	SIOT	ESC	COVID	SBDA	TC	UB	LOP
Significance of AI	SAI		A	V	V	V	X	V	A	X	A	A	A
Lack of resources	LOR			V	V	V	V	V	A	V	O	V	V
Centralized decision making	CDM				V	V	A	O	A	A	A	A	A
Product diversification and JIT	PDJIT					V	A	A	A	A	A	A	A
Revenue generation	RG						A	A	A	A	A	A	A
Significance of IoT	SIOT							V	A	X	A	A	A
Efficient supply chain	ESC								A	A	A	A	A
Covid-19	COVID									V	V	V	V
Significance of big-data	SBDA										A	A	A
Transportation constraints	TC											V	V
Unavailability of buyer	UB												A
Lack of operational performance	LOP												

relationship among the key factors affecting manufacturing industries during Covid-19 using the ISM framework. MICMAC analysis entails the valuable insights of identified key factors through their driving powers and dependence. The critical outcomes of this research are stated hereafter. No such factor resides in the independent quadrant. The autonomous factor constitutes low driving power and weak dependence. It is inferred that there's no unfocused factor that exists in the identified key factors of the study which in turn manufacturers are focusing on all the factors with equal importance.

Factors like revenue generation (F5), product diversification and JIT (F4), efficient supply chain (F7), and centralized decision making (F3) are falling under the dependent quadrant. These factors having high dependence power with low driving powers. They are set up at the peak level of the ISM hierarchy which is shown in Fig. 3. This result represents that revenue generation (F5) is the long-term focus and desired objective of the study which can be achieved by product diversification and JIT (F4). Similarly, product diversification and JIT (F4) may be executed by an efficient supply chain (F7) and centralized decision making (F3). These are the solutions for manufacturing industries during Covid-19.

There are three factors like F1, F6 and F9 are visible in the linkage quadrant. These factors are having high driving with high dependant power which is considered as unstable factors. Any modifications to these factors will influence other factors and also feedback on themselves. The outcome reveals that the significance of artificial intelligence (F1), the significance of the internet of things (F6), and the significance of big data analysis (F9) are unstable in manufacturing industries as per the interpretation of MICMAC analysis. In this study, these factors have been termed as initial solutions as shown in Table 1 and these factors are leading all the solutions like product diversification and JIT (F4), efficient supply chain (F7), centralized decision making (F3), and eventually revenue generation (F5). Hence digital technology is considered as the vaccine for manufacturing industries during Covid-19.

The factors like F8, F2, F10, F12, and F11 are categorized as driving factors or independent factors due to their more driving power with less dependent power. These short-term-focused factors are placed at the bottom of the ISM hierarchy and taken into consideration as strategic orientation factors. Covid-19 (F8), lack of resources (F2), transportation constraints (F10), lack of operational performance (F12), and unavailability of the buyer (F11) are the real challenges during Covid-19 and are considered for immediate attention to driving other factors toward accomplishing the favored objective like revenue generation. It is essential to enhance constantly independent factors like Covid-19 (F8), lack of resources (F2), transportation constraints (F10) will enhance the performance of manufacturing sectors during the pandemic.

The discussion elucidates several lessons learned that are highlighted as:

- Covid-19(F8) is the short-term focused factor that has forced the manufacturing industries throughout the world to rethink the strategy of their operations.
- The challenges to be addressed due to F8 are the independent or driving factors such as lack of resources (F2), transportation constraints (F10), lack of operational performance (F12), and unavailability of the buyer (F11). These require high priority immediate focus to be resolved to attain the ultimate long-term goal of revenue generation (F5).
- The high driving and high dependence power or unstable factors are the linkages between "problem" and "solution" factors. These provide the platform to bring about solutions for the immediate problems under Covid-19. These are the significance of artificial intelligence (F1), the significance of the internet of things (F6), and the significance of big data analysis (F9). These are termed the "initial solutions" in the ISM model proposed.
- The dependent factors are the solutions or the objectives that need to be achieved to bring forth the "final objective" of revenue generation (F5). These are the solution aspects of the model. These are centralized decision making (F3), efficient supply chain (F7), product diversification and JIT (F4), and Revenue generation (F5).

Hence it is summarized that digital technology like the significance

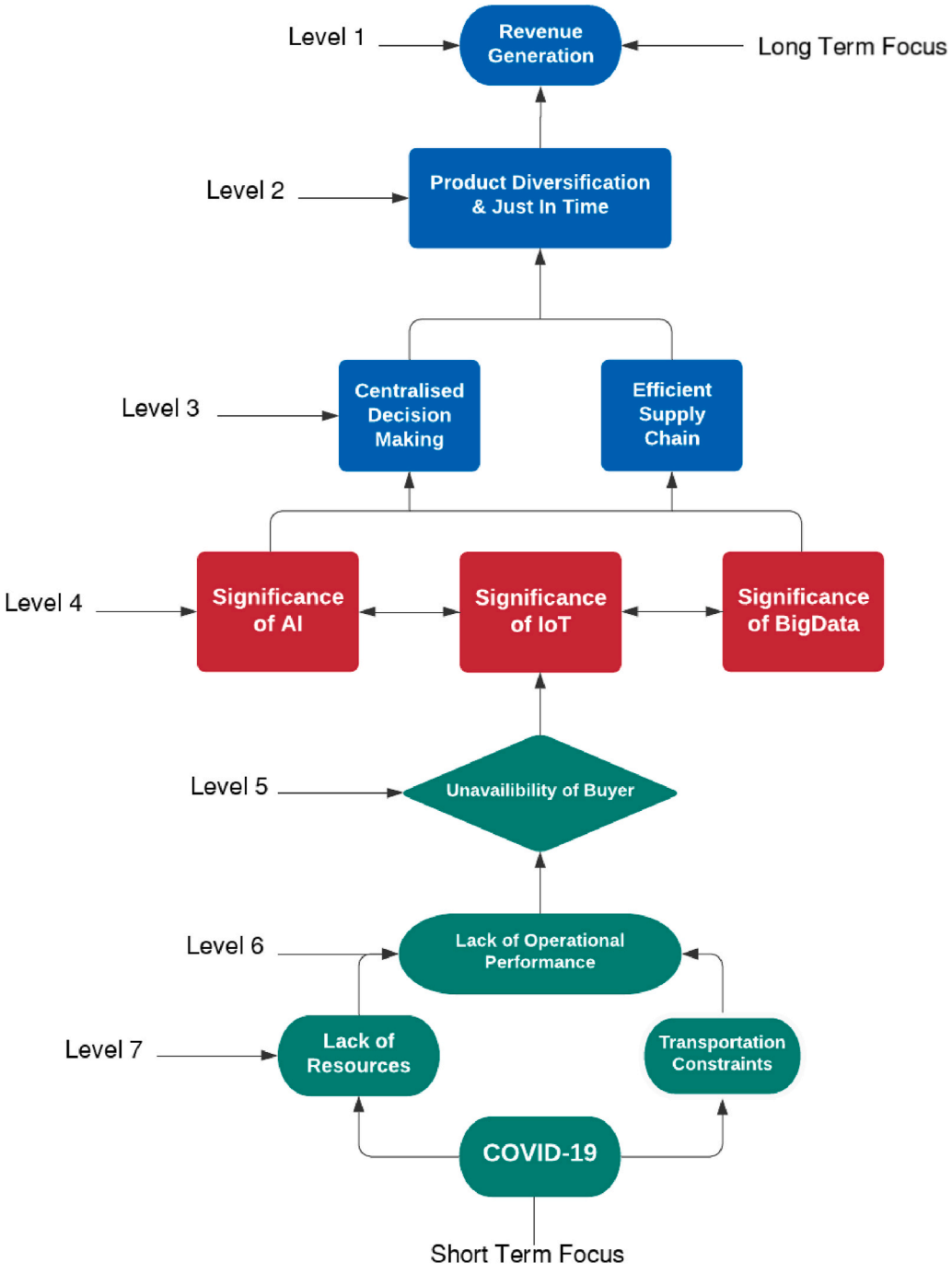

Fig. 2. Interpretive structural model.

of artificial intelligence, the significance of the internet of things, and the significance of big data analysis is the key initial solution of the challenges like Covid-19, lack of resources, transportation constraints, lack of operational performance and unavailability of buyers.

The unique interpretation of ISM analysis in this research illustrates the following:

- ➢ This paper interprets the result where inputs like the pairwise relationship between the factors based on expert opinion.
- ➢ The contextual relationship entails the influencing nature of the factors, such as the significance of AI, IoT, and big data are leading the centralized decision making to make supply chain efficient where most works of literature are prioritizing strategies, time to recovery, time to restore and performance impact to build supply chain efficient ((Amine et al., 2021), (Biswas & Das, 2020)).
- ➢ The outcomes of MICMAC analysis communicate that significance of AI, IoT, and big data are in the linkage phase which indicates that these technologies are still in an unstable zone for most of the manufacturing industries. Where some past authors have not considered the significance of these digital technologies for manufacturing competitiveness in Covid-19((Deshmukh & Haleem, 2020), (Lu et al., 2021)).

5. Practical implication

The practical implications of the research are evident. The industries

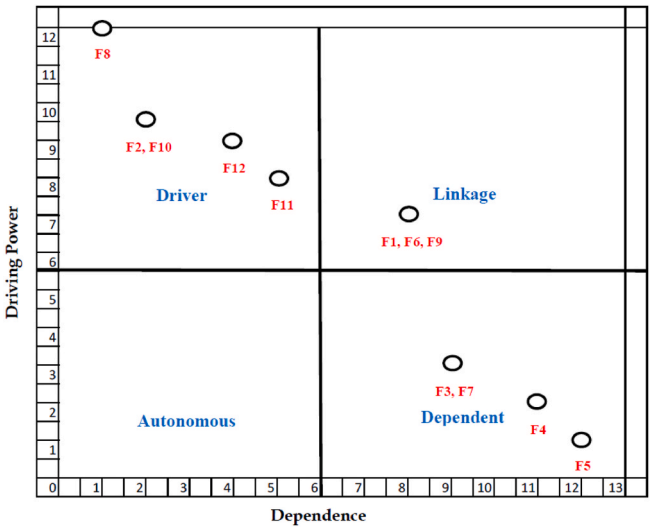

Fig. 3. MICMAC analysis.

which are collapsing under the pressure of the novel corona virus have to reinstate themselves by modifying their strategies. This model will aid in their visualization of the pathway to initiate the change. The managerial implications for the research are:

- The model is a solution to tackle the lack-luster and struggling scenario of manufacturing industries
- Digital technology is the apparent rescuer to mitigate changes in strategy
- Revenue generation is the practical goal to the survival of any industry, to which managers are committed; this research may act as a catalyst to reinforce implementations.

The resources that are represented by 4M's (Material, Men, Machine, and Money) are being squeezed by the pandemic. Under such circumstances, it turns into an important venture to generate revenue for the industry. The lack of raw materials is evident due to "lockdown" in diverse parts of the world (Gupta, Abdelmaksoud, Jafferany, Lotti, Sadoughifar, Goldust). The entire supply chain is likewise disrupted with no adequate workforce and demand/needs as to previous/ordinary conditions (Ivanov & Dolgui, 2020). The machinery under breakdown situations can neither be repaired nor replaced with new ones. The corona virus outbreak uncovers the risk of over-reliance on just-in-time (JIT) and lean delivery systems. As alternatives, smarter logistics, and reverse logistics systems for secondary materials and waste products can be enabled with the aid of using IoT technology is well expected. The trends towards "glocalization"- both global and local aspects are localized by the worldwide network, collectively they are considered as motivating prospects. Lean, referred to as a "warrior philosophy" can assist to enhance work-life with limited resources (Sarkis et al., 2020a).

This study will be a guiding principle for the stakeholders of the manufacturing sectors concerning the significance of digital technology in the manufacturing sectors in the course of the pandemic scenario. The forecast of the virus can make it restricted or perhaps stall the spread of the virus. And finally, it's going to cause automation of tasks and enhance manufacturing efficiency to attain revenue generation ((Mantelero, 2018); (Duan et al., 2019)). Production planning, quality control, preventive maintenance and machine inspection are a number of the applications that are served with the aid of using AI in today's era. IoT is likewise another key solution during the epidemic. IoT will permit the manufacturers concerning distribution information monitoring in far-off locations, analysis of the facts obtained, and controlling the process. IoT will provide the smart distribution of products through a temperature and humidity controlled environment with a tracking facility. Big data is the collection of facts associated with Covid-19 being acquired from across the world. The data is collected employing mathematical modeling. To perceive geographical hotspots, create death prediction models, also providing probable estimates concerning the need for sorting out supplies, and decision-making among policymakers, fitness care providers, and key stakeholders (Allam and Jones, 2020a). For policymakers, the research will act as a strategic guideline that would consider adjusting the existing policies and making new ones, which eliminates the redundancy of existing policies pertaining to the new covid era industrial paradigms.

It can be outlined that digital technology which includes AI, IoT, and BDA influences product diversification and just in time through process automation and an efficient supply chain. Hence digital technology is impacting the solution to demanding situations like lack of operational performance and unavailability of buyers.

6. Conclusion

The pandemic effect of Covid-19 has paralyzed the manufacturing sectors globally which motivated the researchers to find out the amicable solution for numerous challenges. Digital technology is the backbone in achieving the target of revenue generation of manufacturing organizations in the coming days. However, some industries like electronics, smart phones, and automobile sectors have been adopted digital technology for process automation and efficient supply chain to gain revenue through customer satisfaction. Hence it is very much needed to examine the key factors that are accountable for energizing the manufacturing industries nowadays. This study extracted twelve key factors through critical literature reviews that are influencing the manufacturing industries during Covid-19. Finally, the interrelationship between these factors is leading to an interpretive structural model with seven levels as shown in Fig. 2.

In this ISM, revenue generation is located at the peak of the hierarchy and termed as level 1 which is most dependent on other factors. Hence, revenue generation is considered as the desired goal of the study and the long-term focus factor. On the other end, the impact of Covid-19 is

Table-5
Level partition.

Factors	Notations	Reachability Set	Antecedent Set	Intersection Set	LEVEL
1	SAI	1,3,4,5,6,7,9	1,2,6,8,910,11,12	1,6,9	4
2	LOR	1,2,3,4,5,6,7,9,11,12	2,8	2	7
3	CDM	3,4,5	1,2,3,6,8,9,10,11,12	3	3
4	PDJIT	4,5	1,2,3,4,6,7,8,9,10,11,12	4	2
5	RG	5	1,2,3,4,5,6,7,8,9,10,11,12	5	1
6	SIOT	1,3,4,5,6,7,9	1,2,6,8,9,10,11,12	1,6,9	4
7	ESC	4,5,7	1,2,6,7,8,9,10,11,12	7	3
8	COVID	1,2,3,4,5,6,7,8,9,10,11,12	8	8	8
9	SBDA	1,3,4,5,6,7,9	1,2,6,8,9,10,11,12	1,6,9	4
10	TC	1,2,3,4,5,6,7,9,10,11,12	8,10	10	7
11	UB	1,3,4,5,6,7,9,11	2,8,10,11,12	11	5
12	LOP	1,3,4,5,6,7,9,11,12	2,8,10,12	12	6

placed at level 7 which influencing other factors with its strongest driving power. Hence, Covid-19 leads to resource constraints. Transportation constraints ultimately drive towards the unavailability of buyers due to a lack of operational performance. Then, MICMAC analysis was performed. The recognized factors are categorized into four distinct clusters, based on their driving and dependent power. The results of the study reveal the nonexistence of independent factors. There are four dependent factors, three linkage factors, and five independent com driving factors as shown in Fig. 3. The identified independent factors such as Covid-19 (F8), lack of resources (F2), transportation constraints (F10), lack of operational performance (F12), and unavailability of the buyer (F11) are the real challenges cum drivers of manufacturing sectors during the pandemic scenario. Therefore, immediate care should be taken to these challenges. Similarly, factors like revenue generation (F5), product diversification & JIT (F4), efficient supply chain (F7), and centralized decision making (F3) are dependent factors cum real solutions to the manufacturing industries during an epidemic environment. But the policymakers should more concentrate on digital technology factors such as the significance of artificial intelligence (F1), the significance of the internet of things (F6), and the significance of big data analysis (F9) which are unstable in nature. Therefore digital technology factors are the initial solutions to the real challenges like lack of operational performance and unavailability of the buyer during Covid-19 and a solution provider to achieving revenue through product diversification with just-in-time production, efficient supply chain, and process automation.

This research has a deep impact on the manufacturing industries of the world that are searching for various ways to enhance their production and revenues during the novel pandemic situation. The model is a formidable way to visualize the problem and its associated solutions through the application of the latest technology to get back to the track. The renewed strategies that could be devised for which this research is a precursor will definitely solve the problem in all types of industries. The variety of applications of the same concept will cater to the needs of different industries. The outcomes of the interpretive structural model provide valuable information and deep insights to the stakeholders of manufacturing sectors regarding the significance of digital technology factors. The advanced analytics and digital technology gave new insight into the flexibility of data storage. The significance of AI, IoT and big data are all opening the gates to the amalgamation of digital technology. The balance between driving factors and digital technology is serving a key role in minimizing the limitations in the manufacturing sectors which are brought in by digital technology. The limitations of this research are the potential future scope for other researchers. The limitations of the research are that it is based on the assumptions that the concerned industries have the resources and the will to make a changeover in technology, which is mostly the case. The success of this predicted ISM model largely relies on the way things are implemented. Digital technology can be a “game-changer” in such critical situations only when applied intelligently. In the future, more factors regarding the performance of the manufacturing sectors can be added to obtain a more clear view of this study. Statistical modeling and a fuzzy approach may be used to get more dimensions of the factors. No doubt, the critical findings of this study will be a guideline to realize the weightage of digital technology to the stakeholders of manufacturing sectors to achieve revenue in the post-covid industrial era.

CRediT authorship contribution statement

Biswajit Mohapatra: Conceptualization, Methodology. **Sushanta Tripathy:** Experts survey, Writing – original draft, Preparation. **Deepak Singhal:** Writing – review & editing. **Rajnandini Saha:** Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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