From Digital Transformation to Sustainability in SMEs: Opportunities for Net Zero Economy

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Abstract

Small and medium enterprises (SMEs) are major contributors in economy as well as employment of emerging markets. These SMEs can be categorized into service or manufacturing based industries. Manufacturing sector in SMEs are now being supported by large enterprises as well as many multi-national corporations for service deposition and their expertise in manufacturing of specialized goods. This is the reason these SMEs are now digitalizing their business models and expanded their market to global level. In this context, large enterprises are also providing Industry 4.0 based solutions to these SMEs to align them with their business models. However, these industries are also realizing the need to reduce environmental impacts of manufacturing by incorporating disruptive technologies i.e., additive manufacturing and IoT in their organizations which comes under Industry 4.0 umbrella. The studies in literature have highlighted the potential benefits of these technologies to improve economic performance but less attention have been paid towards the sustainability performance in terms of environmental and social benefits. To address this issue a theoretical framework for SMEs is proposed which can be used to enhance their environmental performance. The proposed framework is validated in the leading manufacturing SMEs which have incorporated the additive manufacturing operations in their organizations to reduce environmental impacts and improve economic performance. The study also highlights the role of disruptive technologies on the sustainability and discuss how these technologies can improve the economic and environmental performance. The findings indicated that disruptive technologies can improve the environmental performance and create a sustainability roadmap in the initial journey of Industry 4.0 practices for SMEs.

Keywords
Industry 4.0, roadmap, additive manufacturing, SMEs, sustainability; net zero economy

1. Introduction
Industries have seen many major developments in the manufacturing between the 17th to 20th century due to rapid advancements in information and technology. In literature Industry 4.0 is discussed as fourth industrial revolution which can provide mass customization and greater flexibility to the manufacturing systems across the shop floor and supply chain level (Almada-Lobo 2015). All the disruptive technologies which appeared in literature i.e., CPS, IoT, Blockchain technology, cloud computing, big data analytics and additive manufacturing comes under the Industry 4.0 umbrella. The role of artificial intelligence approaches such as: machine learning and deep learning is also well discussed in literature to support Industry 4.0 shift (Klingenberg et al. 2019; Vestin et al. 2020). Various authors have reported about the different definitions of Industry 4.0 in last years but still it is an area of debate due to difference in opportunities for developed and emerging markets (Furstenau et al. 2020; Kim 2017). The similar terms such as: digitalization, Industry 4.0 and fourth industrial revolution have also discussed in the literature to define the new industrial shift in various regions of world. The literature also highlighted about the impact of these practices on the sustainable performance of organization (Alcácer & Cruz-Machado 2019; Jamwal, Agrawal, Sharma, & Giallanza, 2021; Stock & Seliger 2016). The alternative way to achieve this can be adoption of sustainable manufacturing in these organizations. The benefits of these practices can be carbon emission reduction, sustainability promotion, healthier soil, clean water and workplace (Sharma et al. 2020).

However, various industries are adopting these practices with Industry 4.0 technologies which can improve the environmental performance and create a sustainable future for humans (Beltrami et al. 2021; Raj et al. 2020). For instance, (Enyoghasi & Badurdeen 2021) highlighted how disruptive technologies impact the sustainability performance of an industry. The role of technologies i.e., Artificial intelligence and machine learning is also discussed by few studies in relation with environmental sustainability. For instance, (Carvalho et al. 2019; Jamwal et al. 2021b) argued that carbon emission, energy consumption and resource efficiency related issues can be handled by machine learning approaches. More precisely the deep learning approaches can be used to improve the predictive maintenance and quality management related issues in the manufacturing industries (Ayvaz & Alpay 2021). As discussed in literature there is less evidence about the sustainability benefits of Industry 4.0 practices and their impact on net zero economy. Therefore, the present study aims to develop a digital transformation roadmap which can help to achieve sustainability and net zero economy.

Also, the study highlighted the different challenges for the industry 4.0 business models in Indian context. These studies have highlighted the role of sustainability related tools and measures in Industry 4.0 practices. But studies related to both these concepts are still limited in terms of validation in developing or low-income economies due to lack of Industry 4.0 practices in SMEs. The low income and developing economies are majorly dependent on the SMEs sector to fulfil the customer demands and have a major role in the development of economy. Lack of technological support and infrastructure facilities are the major barriers which influence the sustainability practices in Industry 4.0. The role SMEs in the development of Industry 4.0 is very important. There is need of different roadmaps for both SMEs and large enterprise due to difference in their operational and managerial aspects. However, in some developing countries like India the MSMEs ("Micro-small and medium enterprises") are more popular as it contributes more to the Indian economy. The next sections of paper discussed about challenges associated with Industry 4.0, Industry 4.0 for net zero economy, Digital roadmap for SMEs, Current maturity for digital transformation and validation through case study.

2. Addressing manufacturing challenges with Industry 4.0

There are many opportunities for business for SMEs in Industry 4.0 era but few of major challenges are associated with these practices for emerging markets (Furstenau et al. 2020; Kowalikova et al. 2020; A. Kumar & Gupta 2020). SMEs of emerging markets are still struggling to deal with these challenges. The lack of proper cash flow is one of the significant challenges for MSME and SME sector of emerging markets (Luthra & Mangla 2018). Automation and Digitalization practices requires high investment costs (Mittal, Romero et al. 2018). Difficulty in raising capital in the initial stages of the Industry 4.0 implementation limits the Industry 4.0 adoption in the these SMEs. The another significant challenge is lack of skilled labour (G. Yadav, Luthra et al. 2020). Most of the labour in the SMEs still follows the traditional training methods which makes difficult to operate new disruptive technologies in these organizations (Bag et al. 2020).

In this regard, a local manufactured technological solution will be helpful for these SMEs which can complete the automation requirement for SMEs at the shop floor level (Mittal et al. 2018b; Tayal et al. 2017). This will help to reduce the time consumption in the traditional factories and minimize the fatigue of labour in the long working hours (Abbasi & Kamal 2020; Bai et al. 2020). Most of the SMEs which served the global markets are now adopting new technologies at lower costs with the help of available Industry 4.0 solutions (Yadav et al. 2020b). These technologies are helping them to build the stronger customer relationship, lower maintenance times, real-time process monitoring and control, better data management, better transparency in the manufacturing activities (Wagire Joshi et al. 2020). The Industry 4.0 based solutions are also helping SMEs to improve their environmental performance, producing sustainable products and maintaining transparency in their supply chains (A. Kumar et al. 2022). The other new opportunities for SMEs with Industry 4.0 technologies are digital platforms for product customization (Amaral & Peças 2021). This is helping the SMEs to improve their market reputation and improving business models.

2.1 Industry 4.0 for Net zero economy

Rapid growth in the industrialization and globalization has results in excessive generation of carbon emission which is impacting human health and animals. Few strategies have been proposed in last few years to handle the issue of carbon generation from the industries. Manufacturing activities are the major source for carbon emission as well as greenhouse gases generation. These days all manufacturing industries are investing in the smart budgets to increase their sustainability performance. Sustainability is the main priority in manufacturing organization to achieve their environmental and economic goals. The manufacturing industries can transform themselves in the net zero factories

in which they can follow the net-zero pledges. There are several ways by which manufacturing organization can achieve their net zero vision in manufacturing organization. The manufacturing organizations can experience these benefits related to: energy efficiency, material recycling, clean water, food and clean soil. The various Industry 4.0 tools can help to achieve Net zero economy vision (Okorie et al. 2023).

1. Artificial intelligence and Internet of things: It can provide autonomous manufacturing facilities at the shop floor with various optimization algorithms which can lead to net zero pathways in the organization.
2. Digital marketing with artificial intelligence: Digital marketing can be done with the help of Artificial intelligence tools. The data collected from the consumers can be used for demand forecasting purposes which can help the industries to reduce the overproduction.
3. Enterprise resource planning with cloud technology: Cloud technology enables the cloud-based enterprise resource planning which help to reduce the costs as well the exchange the productivity improvements done by the organization.
4. Robotics: Adoption of robotics technology in the organization help to minimize the accidents in the critical areas within the shop floor and also improves the work performance. It also reduces the raw material consumption and wastage during the manufacturing process. Human error defect can also be eliminated with the help of robotics.
5. IoT for improving operational efficiency: With the IoT network interconnected devices can communicate with each other in a centralized way. This will help to improve the operational efficiency of the organization.
6. Smart grids: The smart grids will helpful for smart distribution of energy through the digital communication. Adopting the smart grids will help to achieve the net zero economy.

3. Digital roadmap development for SMEs

Industrial shift has changed the business models and now SMEs are also adopting disruptive technologies to improve their supply chains. The impact of supply chain sustainability is well discussed in literature to improve the organizational performance. However, SMEs are still lagging with maturity of these technologies due to limited awareness and resources. For SMEs there is need to understand the challenges and success factors before developing the further digitalization roadmap. The available literature on Industry 4.0 have highlighted about these challenges but the sustainability perspective is still not fully explored in these studies. There is still need to find out the impact of these challenges on the sustainability performance also. Also, the studies reported about the different challenges are from both emerging and developed markets which cannot be generalized. As discussed by (Bhanot et al. 2015) implications related to the sustainability changes across the geographical regions due to local laws and issues. There is need to validate the challenges and success factors in the geographical region by conducting a survey in which statistical approaches can be used for validation.

In this study, an Indian industry is considered. Indian manufacturing sector is emerging market and produces electronics and automobile goods. In this sector SMEs are important which are now supported by the multi-national companies due to favorable policies by Indian Government and less labour costs. Few of industries from this SMEs have recently started their digitalization journey by adopting disruptive technologies and developing a digital roadmap. Generally, a digital roadmap can be considered as the strategic roadmap which holds the central place in Industry 4.0 implementation. The digital roadmap also adds a strategic perspective to the manufacturing SMEs. The SMEs are influencing by number of factors related to social, economic and environmental related challenges in Industry 4.0 practices while the implementing the digital manufacturing platforms. The study acknowledges the initial efforts in the digital transformation roadmap developments such as: (Akdil et al. 2017; Alcácer et al. 2021; Angreani et al. 2020; Mittal, Khan, et al. 2018; Schumacher et al. 2019; Verhulst & Brenden 2021; Wagire, Joshi, et al. 2020).

The present study follows these guidelines for roadmap development and the sustainability perspective have been added in the framework. To explore the holistic view of Industry 4.0 major maturity dimensions were considered which is presented in the Figure 1. In the initial level proposed framework suggested to execute the Industry 4.0 technologies at the initial phase which can further provide the sustainability benefits in terms of carbon neutrality, 6R strategies, clean water and soil. The digital transformation map for sustainability is discussed in the Figure 1 in which connection between major maturity dimensions of Industry 4.0 have been presented. The framework considered the current level of industry, short term goal-1, short term goal-2 and long-term goal for sustainability in with digital transformation. Although, different Industry 4.0 technologies have a positive impact on the sustainability performance of the industry. But industries need to ensure about the culture of continuous improvement to achieve sustainability

through Industry 4.0 technologies. Blockchain technology helps in the better traceability of resources as well as a positive impact on the waste management and reduction in energy waste. The framework proposed helps to visualize how maturity dimensions can improve the business performance and have an influence on the sustainability at system, process and product level. Sustainability in business needs continuous improvement culture. Industry 4.0 technologies offers a wide range of opportunities for SMEs in sustainability.

SMEs should focus on the: a) "Why", Why sustainability in the business is required? What opportunities can sustainability brings in future? This requires training and awareness regarding both sustainability and Industry 4.0 b) "What", in which industries need to define their goals. The goals may be related to environment or economic performance. These goals can be short term goals or long-term goals. These all strategies are adopted in literature such as: (Verhulst & Brenden 2021) In this phase role of management is important to take effective decisions or release smart budgets to promote sustainability initiatives. Also, as discussed by (Enyoghasi & Badurdeen 2021) sustainability in Industry 4.0 can be at three level industries need to be clear about the type of sustainability they required in their business model. Industries should have a clear vision regarding goals of industry for sustainability or Industry 4.0 practices c) "How", in these industries need to make effective strategies that how their projects will be implemented? How the challenges will be tackled? How the strategies and plans will be prioritized?

Assessment of current status of industry is very important to know the current maturity level before the development of future strategies for Industry 4.0 practices. Industries of developing nations are far away from the technological advancement requirements for Industry 4.0. Industries need to ensure about their current level and readiness before the development of any strategies related to Industry 4.0 practices. The current industry status for Industry 4.0 depends on many factors such as: resource availability, maturity of different technologies, zero paper strategy, management support, cloud computing, R&D of industry. The challenges related to Industry 4.0 practices and enabling factors are also find out for the industries.
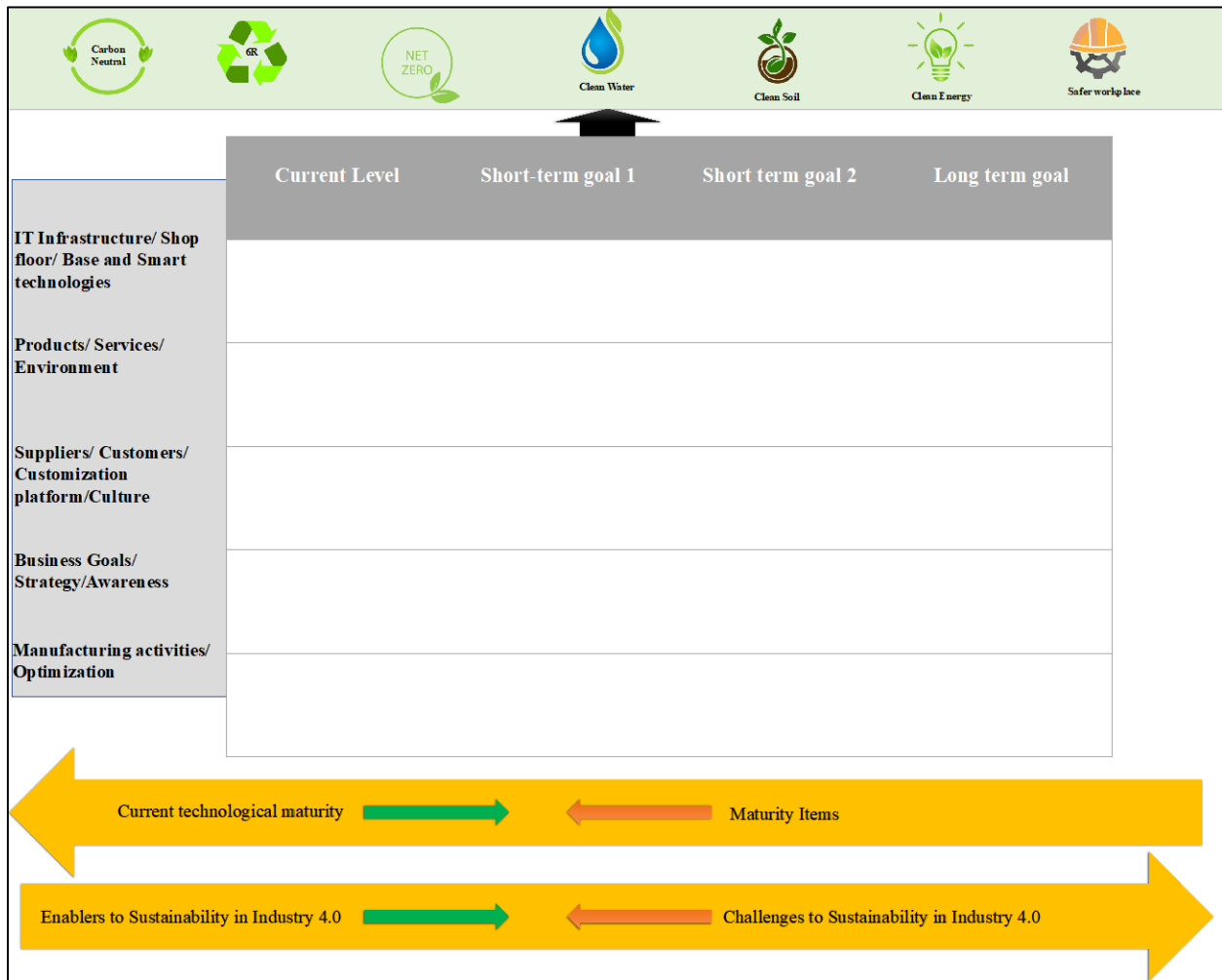
Figure 1. Digital roadmap for SMEs to achieve net zero economy (Verhulst & Brenden, 2021)

4. Current maturity for digital transformation

SMEs visions for digital transformation and agility to adopt new disruptive technologies in organization plays an important role to development digital roadmap in industries. At present Industry 4.0 encompasses implementing IoT, AI and ML based solutions in SMEs due to increasing dynamic market demand and competition. Emerging economy like India can be considered as one of fastest growing market which is also experiencing huge demands because of volatile market changes and globalization. It is important for SMEs of India to embrace the investments in new technologies which can improve their manufacturing operations to complete market demands and external market competition. It is true that Industry 4.0 shift has unlocked new opportunities for environmental and social sustainability for SMEs. It is true that Industry 4.0 tools and technologies have potential to unlock the opportunities for sustainability as well as sustainable development goals. But industries need to focus on the current status of their technologies so that they can plan the strategies for the future actions related to Industry 4.0. Industries should focus where the organization wants to be in next five to ten years from its current status. As, Indian industries are in its initial development stage for the Industry 4.0 practices. Most of the technologies related to Industry 4.0 are still at low maturity level in case of SMEs. The basic template for the Industry 4.0 practices is presented in the Figure 2 which can be used for the maturity assessment in case of SMEs of India. It is important to assess the maturity after a specific period of time to know about the improvement. As, Industry 4.0 practices requires a strong commitment and continuous improvement culture. Only with the help of continuous improvement culture industries will be able to achieve sustainability the business practices.

4.1 Industry 4.0 practices and SMEs

Various activities and the objectives are associated with the Industry 4.0 practices which follow a timeline given by organization to achieve its goal in the five specific dimensions discussed in the roadmap. In the initial phase, each dimension is assessed separately and readiness of industry is measured on the current status for the particular dimension. Further, the objectives set for the future and strategies developed for the future action within a specific timeframe. Each dimension and objectives associated with these dimensions will be effectively monitored by the dedicated team for the Industry 4.0 practices. It is ensured that all the objectives are aligned to the implementation and must support each other. The objectives should not have a negative impact on the time and financial constraints of the organization.

4.2 Opportunities and challenges

This helps to give an overview of both internal and external factor which affects or support the Industry 4.0 implementation in the organization. It is true that achieving business sustainability with the Industry 4.0 tools and technologies requires continuous improvement culture in the industries. But, in the initial phase before developing any strategy related to Industry 4.0 industries need to understand about the success factors as well as challenges in the implementation phase. In case of developing nation, the success factor and challenges may vary to industry type, industry sector, geographical region and financial constraints. The framework proposed in this study for SMEs will help to get an idea about the different alternative routes for the Industry 4.0 implementation by assessing current stage and developing future strategies for the industries. This framework provides an detailed overview of actions included in the each dimension with a timeline which represents what are the next steps and projects related to business sustainability with Industry 4.0 practices.

The main challenges faced by SMEs in their sustainability goal with Industry 4.0 technologies are as: (1) Volatile market demands (2) Lack of design standardization (3) Less management readiness (4) Less technological readiness (5) Optimized supply chains (6) Less knowledge about energy efficiency and consumption strategies (7) Rigid culture and organizational structure (8) Less flexibility on the shop floor and supply chains (A. Kumar et al. 2022; Luthra & Mangla 2018; Machado et al. 2020; Mittal, Khan, et al. 2018; Sharma et al. 2020; G. Yadav, Kumar et al. 2020). The other related opportunities and challenges for manufacturing SMEs from emerging markets are:

(1) Manufacturing challenges: The manufacturing organization may face some key challenges in their business models which are: (1) Lack of clear vision (2) lack of knowledge about advanced data analytics tools (3) lack of standardization (4) lack of Industry 4.0 architecture (5) Lack of funds (6) Data security issues (7) Rigid management structure (8) Storage issues for large volumes of datasets (Bajic et al. 2018; R. Kumar et al. 2020; Luthra & Mangla 2018; Mittal, Khan et al. 2018)

(2) Skill challenges: Majority of industries are facing with the lack of skills in SMEs which is limiting the Industry 4.0 adoption in the manufacturing SMEs. However, we argued that it can be improved by investing on the training programs. The another myth behind Industry 4.0 adoption is loss of jobs due to automation. There is need of social acceptance of Industry 4.0 wave to experience the benefits of Industry 4.0 in the business models. Industry 4.0 will help to create the new jobs as well as new opportunities for sustainability in the area of analytics (Fachrunnisa & Hussain 2020; Luthra & Mangla 2018; Mittal, Khan et al. 2018; Moldovan 2019; Wagire, Rathore et al. 2020).

5. Framework validation

5.1 Initial validation process

The framework for SMEs which will help to achieve their sustainability goal through the digital transformation was developed after conducting literature review and following the industry reports available on the open-source information. A SME from India which is working on the digital transformation was considered for the case study. SMEs in India are the major contributor to generate employment as well as boost economy. Majority of SMEs from the manufacturing sector are from automobile, pharmaceutical, electrical and electronics sector. In the present case a SME located in the South region of India is considered as the case organization. The organization deals with the manufacturing of die which is further used by automobile industries. The organization manufacturing these dies with both conventional and new processes such as: additive manufacturing. In the first phase of the study life cycle assessment was done to identify the environmental impacts generated from both the processes (A. Yadav et al. 2021).

The results of life cycle assessment indicated that impacts are more in case of conventional processes. There were less impacts when using the additive manufacturing process. Further, industry adopted the additive manufacturing as the primary process in their manufacturing activities. Die manufacturing industries are basically manufacturing industries which works on die manufacturing with the metal as a material. Government of India is also promoting these industries by many schemes. The main aim to promote the new tools and technologies in these industries to make India as the manufacturing hub which is previously to be imported from many overseas countries.

In the initial phase a virtual meeting was conducted with the manager and project team in which basic Industry 4.0 concept, its technologies and their benefits to improve the economic and environmental performance was discussed. In the next stage a questionnaire was developed and shared with the team for manufacturing data to conduct the life cycle assessment for both the processes. After, conducting the life cycle assessment one more session was conducted with team to gain their insights to include the Industry 4.0 technologies in their manufacturing activities. In the end a semi-structured interview was conducted with the industry experts to provide the insights and evaluation of roadmap developed for the digital transformation.

5.2 Framework validation
The XYZ industry is located in the Southern region of India and have manufacturing facility in their plant. The industry has 100+ employees and different types of advanced machines which used for different types of operations. Figure 2 shows how the industry going to utilize the framework in the future. The framework shows the current status and future plans of the industry. The main purpose of developing framework was to check the whether the developed framework is supporting Industry 4.0 initiatives in the company. This framework can help the industries to set the future objectives and get an idea about the implementation of Industry 4.0 initiatives. The various Industry 4.0 tools and techniques helps to create sustainable value creation at system, process and product level in the manufacturing organizations.

6. Findings and discussions
The case was conducted on the framework to check the practical applicability of the framework. During the discussion with the team members it is found that a digital roadmap can help the industries to monitor their progress and work on the their goals to improve the environmental and economic performance. This also help the industries to sustain their market value in the competitive era when there is the demand of sustainable products or follow the environmental regulations. The challenges related to sustainable manufacturing were also investigated in this case with the Industry 4.0 perspective which also help the industry to improve their critical areas and processes. The other benefits of the proposed framework is that industries can prioritize their economic and environmental goals as this framework can provide a holistic view of Industry 4.0. The findings also indicates that digital transformation can be achieved by regular employee training. However, incentives related to the sustainability will help the industries to motivate their workers to follow the regulations and develop a safer workplace. The progress of digital transformation was slow in the initial phase as most of the technologies are not enough mature and require more in depth understanding. The continuous improvement approach at all levels including the shop floor activities help to achieve the sustainability goals of industry. The findings reveals that the framework provides an insight about the how different tools and technologies of Industry 4.0 can make a positive impact on their environmental and business performance. For example, case organization was working on the mass customization concept with the help of different 3D printers which is able to complete different customized market demands, scrap reduction and material costs. The results indicated that use of Industry 4.0 technologies can help to improve the environmental performance in terms of reducing the carbon emissions and other impacts. In future, industries can define their long term and short-term goals to improve their market value by adopting the sustainability strategy in their business practices.

Case organization found that at the business level additive manufacturing technology helps to complete the mass customized demands in the shorter time as compared to the traditional approaches which includes: designing, die manufacturing and product manufacturing. However, there was lack with in the information flow due to weak IT infrastructure. Apart from the weak IT infrastructure it is observed that shop floor workers were less aware about the use and benefits of Industry 4.0 technologies. There is need to provide the training programs for shop floor level which will also help to improve the digital skills. Framework help to provide insights for SMEs and suggested to focus on additive manufacturing and use of sensors at the shop floor level. It is also suggested to adopt the digital platforms in the supply chain activities to improve the collaboration and information sharing between suppliers and industry. Development of digital platforms for customization will be helpful for customers to customize their products online

and order directly. In this industry can set up a certain level for customization based on the facility available in their organization for customization. SMEs are still lacking with the maturity of digital transformation due to lack of knowledge and resources. The framework suggests the industries to work on their current level and existing technologies with a vision of continuous improvement rather than adopting new technologies without improvement in existing technologies.
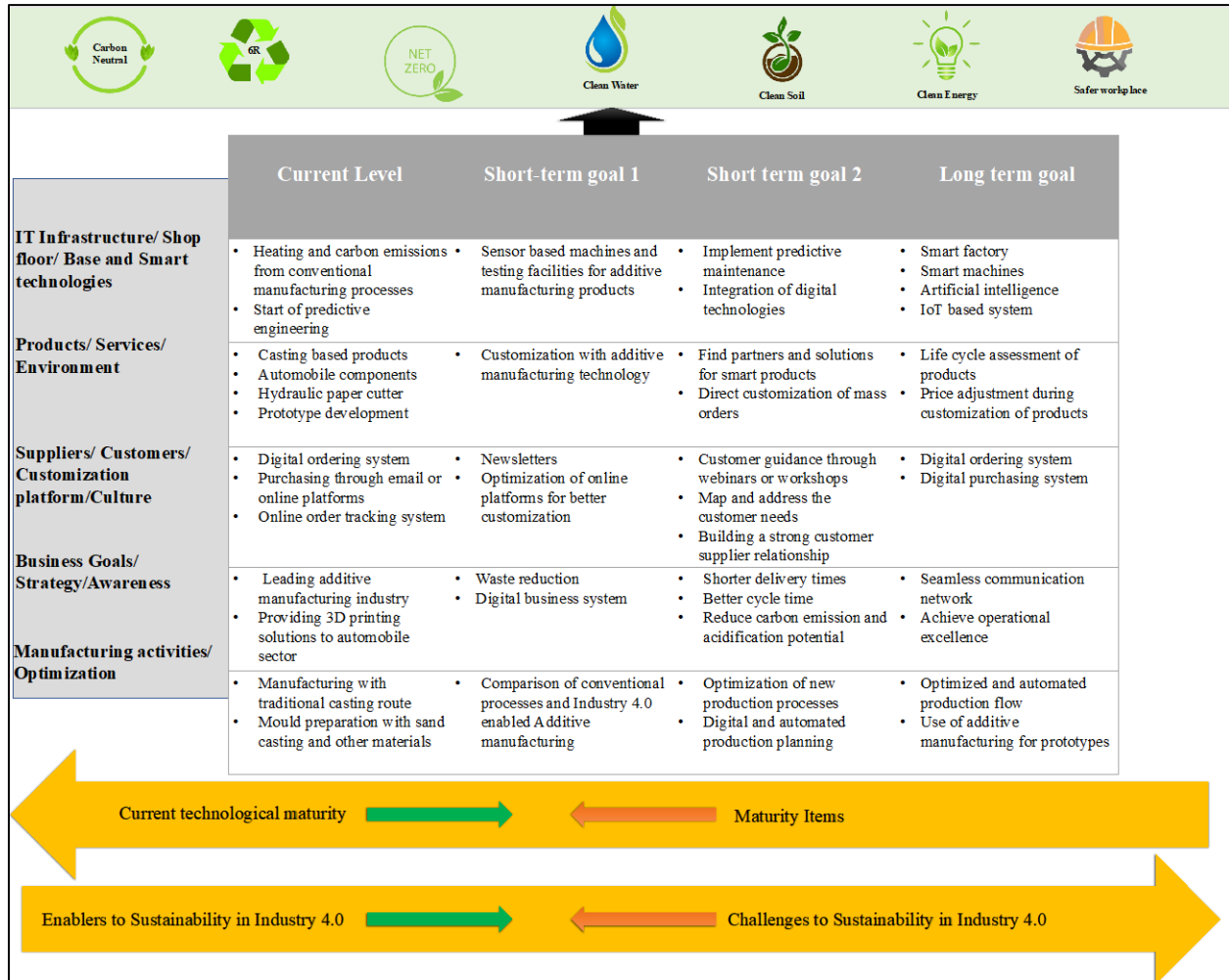

Figure 2. Case study results for framework

6. Conclusion

In the present study a digital transformation roadmap is development which can improve the environmental and economic performance of industry. The framework is proposed for the SMEs which are considered as the major contributor in the economy of developing nations. The framework provides a holistic view of manufacturing organizations by focusing major maturity dimensions. In the study, a case organization from manufacturing sector was considered which provides the insights about the Industry 4.0 practices. The results shows the experience of industry and main changes occurred in the industry in terms of sustainability practices. The case study highlighted that the framework can support Industry 4.0 practices in the SMEs and industry can experience the benefits of Industry 4.0 technologies in terms of sustainability and new business models. In the future studies a digital interface can be developed for the industries and users to check the progress of Industry 4.0 practices over a time-frame. Further, this study can be extended by investigating the application of the proposed framework in other SMEs sectors of the India. In the future, a large survey can be conducted on the SMEs in India and other developing countries to support the Industry 4.0 practices.

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