Role of Sustainable Manufacturing system in Industry 4.0

Prof. Jayashri V. Chopade
Department of Mechanical Engineering
Pimpri Chinchwad college of Engineering and Research, Ravet. Pune, India
Chopadejv91@gmail.com

Dr. Kanchan D. Ganvir
Department of Mechanical Engineering
Priyadarshini Bhagwati college of Engineering, Nagpur, India
kanchan.ganvir100@ mail.com

Dr. Gulab. D. Siraskar
Department of Mechanical Engineering
Pimpri Chinchwad college of Engineering and Research, Ravet.
Pune, India
gdsiraskar@gmail.com

ABSTRACT

This paper focuses on Sustainable manufacturing by which waste can be minimizes and can reduce the impact of environment. Many sustainability tool are to be used to assess the risk of human health, risk of life cycle etc.The objectives of Sustainable manufacturing to introduce the concept of sustainable development and to goals for a society based. To achieve the Sustainability different factors need to consider. This paper also focuses on study of industry 4.0. Industry 4.0 is the alternative way for the companies to manufacture their products, improves the quality of product and and distribute their products in a market so that it can reaches to the customer. Manufacturerig companies trying to use new technologies such as Internet of Things (IoT), cloud computing and analytics, and AI and machine learning for their product to provide the production facilities and throughout their operations. To achieve the green manufacturing, waste management and recycling of waste product plays important role. In this study waste management like recycling of plastic, wood are considered.

Keywords— sustainability; Industry 4.0; Green Manufacturing; material recycling; waste recycling

I. INTRODUCTION

Green manufacturing, sometimes it is called as Sustainable manufacturing (SM),[1] is a production technique which is used to reduce production waste to diminish the impact on the environment. It also minimize the negative impact of environment by using natural resources. Sustainable manufacturing helps to reduce the harm to the local environment. It also helps to reduce the consumption of energy, water, and other limited substances which are available in very less amount. The Sustainable manufacturing also matters because day by day due to climate change and pollution, the public is worried about impact of industry waste on environment. Because of these things it is necessary to take some action and find the effective solution about the waste management and pollution control.

II. SUSTAINABILITY TOOLS

A. Risk Assessment

Risk assessment is a distinctive technique for describing the bad effects of acquaintances on human health and the environment. Risk depiction, exposure impost, dose-response assessment, and hazard identification are the four primary stages that are generally included in risk assessments for human health endpoints. During the hazard identification process, a choice is made on the likely effects of the environmental acquaintance. The dosage response step links the level of negative consequence, such as the frequency of a health effect from an environmental exposure, and the degree of exposure, such as dose or air concentration. The intensity, frequency, and timing of the exposure are described in the exposure evaluation. To produce the metaphors of the risk, the risk characterization integrates dose response and acquaintance assessments.

Life-Cycle Assessment

A "cradle-to-grave" analysis, sometimes known as a "cradle-to-cradle" analysis, considers the environmental effects of a product's manufacture, usage, and eventual disposal. These analyses are used to compare the environmental consequences of various goods, identify process adjustments that could lessen the impact, and analyze the key environmental effects of diverse products. These have already been used by the EPA to analyze the environmental effects of various transportation fuels, and more specifically to determine if biofuels fulfill the standards for carbon-emission reductions in comparison to fossil fuels.

Life-cycle analyses are congruent with, and frequently a key element of, sustainability analysis because they use a systems perspective and consider the entire manufacturing process, from the generation of raw materials to eventual disposal.

Benefit-Cost Analysis

Benefit-cost analysis is a tool used frequently in economics to evaluate the net benefits of various options. A benefit-cost analysis examines the costs and advantages of several possibilities to ascertain how the policy choice would affect each person's wellbeing. After measuring individual net benefits and calculating the societal net benefit, the majority of benefit-cost analyses rank the options. Benefit-cost analysis, which is widely used to examine environmental challenges, has raised concerns that it overemphasizes economic costs while undervaluing benefits and how they are distributed. Recent developments in benefit-cost analysis can be applied to environmental concerns to ensure that the full spectrum of benefits and costs can be taken into account.

Ecosystem Services Valuation

Ecosystem services are products and services produced by ecosystem processes that benefit human well-being. For instance, ecosystems can control water flow, lowering the likelihood of flooding and supplying higher flows during drier periods. They can also filter toxins to offer clean water for human consumption.

The goal of ecosystem-service valuation is to quantify the relative advantages of ecosystem services using a single parameter, typically a monetary one. Ecological and other natural sciences must be integrated in ecosystem-services valuing. Together with economics and other social sciences, it is used to better understand how nature contributes to human well-being ("valuation") and the services that are provided as a result of the state of the ecosystem ("ecological production functions").

B. **Integrated Assessment Models**

The theory and data from other disciplines are combined in integrated assessments to address complicated environmental concerns. The typical method for carrying out an integrated assessment is modeling. Global circulation models and economic models are combined in integrated assessment models, such as the Global Change Assessment Model (GCAM), which were developed in the study of climate change to evaluate the likely advantages and disadvantages of potential energy and climate policy options.

Models used to value ecosystem services are examples of models that combine models from many disciplines to assess the advantages and disadvantages of alternative policy options, even though they are often not referred to as integrated assessment models. The advantage of integrated evaluations is that they include knowledge from several disciplines needed to comprehend how possible significant human influence on the system.

C. **Sustainability Impact Assessment**

An analysis of a project's or proposal's potential implications on the social, environmental, and economic pillars of sustainability is done through a sustainability impact assessment. Integrated policies that "take full account of the three sustainable development dimensions" and incorporate their "cross-cutting, intangible, and long-term considerations" are also developed using this evaluation. The expected environmental consequences of a particular activity and potential alternatives are typically the main areas of attention in environmental impact assessments. With the premise that such consideration will typically (but not always) lessen the environmental impact of the decision, the goal of environmental assessment is to assure complete evaluation of environmental implications and alternatives.

III. FACTORS OF SUSTAINABILITY

Six Key Factors for Achieving Sustainable Manufacturing

A. **Optimize current use of fossil fuels.**

- To save energy, switch a single-speed motor out for a variable-speed or servo drive.
- Employ a hydraulic pump with variable speed.
- Using renewable energy alternatives like hydroelectric, solar, or wind power.

B Eliminate waste.

- Use only the materials and supplies required to create the end project.
- Reduce the time or cost of production.

C. Reduce, or eliminate, pollution

IV. When removing metal, use as little coolant as possible. Another operation that makes use of a lot of potent chemicals is deburring, which involves removing the burrs from finished material after it has been cut.

A. ***Recycle***

V. Large hoppers are utilized to transport the large quantities of metal chips that are produced during the machining and finishing procedures to a recycling plant.

VI. "Chips puckers," machines that compress chips, drain the coolant, and shape the metal into "hockey pucks," which are much easier to transport and use a lot less energy, are one possible answer.

A. **Recover energy, don't turn it into heat**

VII. Energy that shouldn't be wasted is reused.

A. **Save Time**

VIII. Speed up a cycle without consuming additional energy.

IX. Cut down on the number of machines required to generate an equal amount of material.l.

X. Role in Industry 4.0

A. **Industry 4.0**

Industry 4.0 refers to the digital transformation of value generating processes in manufacturing, production, and associated industries. The terms "industry 4.0" and "fourth industrial revolution" are interchangeable, and they refer to a new stage in the management and structure of the industrial value chain. The German government coined the term "Industry 4.0" in 2011 to describe a series of technological advancements in manufacturing systems made possible by automation and ICT (Information and Communication Technologies), including Cyber-Physical Systems, the Internet of Things, simulation and modeling, big data analytics, augmented reality, additive manufacturing, robotics, cloud computing, and now blockchain. It seeks to assist in the operational stages of the integration and fusion of autonomous devices, people, physical objects, and processes in order to produce various types of digital data, functional, and high agility value chains.

B. **The paradigm of Industry 4.0 is implemented in three dimensions:**

- Horizontal integration across the entire value creation network.

  It describes the integration of numerous IT systems utilized at various points in the production and business planning processes, which involve an exchange of resources, information, and products.

End-to-end digital integration across the entire product life cycle.

- It enables the integration of smart business processes throughout the supply chain, including on the factory floor and in CPS services.
- The use of a cloud-embedded ITC for an end-to-end solution is covered by intelligent cross-linking and digitization.
- Manufacturing systems that are networked and integrated vertically.
- During the manufacturing process, it refers to the integration of various IT systems at various hierarchical levels of the Factory itself, from product development to manufacture, logistics, and sales.
- Industry 4.0 is now supported in every industry, including manufacturing, logistics, building, transportation, healthcare, food production, home automation, and even our day-to-day activities with smartphones and watches.

V. LCA related to sustainability within I4.0

A. **Internet of Things (IoT).**

Using sensors, microprocessors, and software systems that can transfer data over networks, this technology lets businesses to link numerous devices that are geographically far.

In this regard, it is important to make clear that such devices are internal to the production machinery and that they can be constructed even after the latter has been finished due to the theory that, in the era of Industry 4.0, any physical entity has the potential to be smart with the intention of disseminating information about its own condition as well as the condition of the environment in which it is located.

Big Data Analytics.

It alludes to a new generation of technology and architectural designs that let businesses to economically extract value by finding, gathering, and analyzing enormous amounts of diverse data. Modern businesses can better utilize the enormous volumes of information they currently possess thanks to big data analytics, which also helps them predict what will probably happen next and decide what measures to take to get the best results. Artificial Intelligence (AI) is the result of it.

B. Cybersecurity.

In order to facilitate the integration of diverse activities, I 4.0 needs access to the environment. While it is imperative that communication channels be set up so that information may be shared, it is also crucial to monitor this sharing in order to safeguard the data flows. Companies need cybersecurity rules to effectively safeguard a device or a device collection in terms of knowledge exchange and data privacy.

C. **Blockchain.**

The foundation for cryptocurrencies like Bitcoin and Ethereum is frequently referred to as distributed ledger technology, but the features go well beyond that. Because it enables transparent, secure, timely, and efficient public or private solutions, blockchain redefines confidence and is permanent and decentralized.

(AR) Augmented reality. One of the most cutting-edge applications in industry 4.0 is being marketed as Virtual Reality, and it makes use of 3D modeling, CAD, and projection technology. In order to analyze the process for improvement during the design and commissioning phases as well as to assist employee training, reference is made to a three-dimensional model that can accommodate a operator. On the other hand, the idea of utilizing particular technologies is mentioned with regard to Augmented Reality.

Robotics and Advanced Manufacturing Solutions.

One of the main triggers is the perception of robots as collaborators of human operators, and this should be the case. Such technologies have the potential to improve the productivity of the firms that employ them and make production processes more efficient. When interacting between automated and manual systems, integrated and automated approaches are supported by human engagement.

In this scenario, robots are true interactive gadgets that may exchange knowledge with humans and other machines while maintaining their autonomy and adjusting their trajectory in accordance with the requirements of the output flow.

D. **Additive manufacturing.**

It is a technique that can print a thing by adding material after creating a digital model of it (with the help of a CAD).

The nozzle has the ability to melt small amounts of powder and build up layers of metal or plastic to form any shape. The potential to move from the digitally codified concept straight to the product without even having to go through intermediary steps is therefore the big promise of this advancement. This will open up space for alternative market models where it is possible to make pieces on demand.

Because it provides a thorough examination of every component of a commodity or service while examining the nature of its whole life cycle, LCA is regarded as the preeminent eco-design technique.

It makes it easier to identify the systems and stages that have the greatest impact, and it also paints a clear picture of the problems that the action objectives must address.

It can be applied to improve the current product or to guide decision-making while creating new products. measurement of consumption and effects, which enables ongoing work and process improvement.

VI. Green Manufacturing

Green manufacturing, as used in the manufacturing sector, refers to the development of environmentally friendly operations and the modernisation of industrial methods. Essentially, it is the "greening" of manufacturing, in which workers utilize less waste and pollution, less natural resources, and recycle and repurpose products. By investigating, creating, or making use of technologies and methods, green manufacturers try to lessen their impact on the environment. The Bureau of Labor Statistics explains that employees in green businesses need to have specialized manufacturing training in green technology and processes, such as:

A. **Energy from renewable sources**

For usage inside the office, employees can generate their own energy, heat, or fuel using renewable resources. These sources include, among others, wind, biomass, geothermal, solar, ocean, hydropower, landfill gas, and municipal solid waste.

Energy efficiency

Specific tools and techniques will be used by staff to increase energy efficiency in the workplace.

Pollution reduction and removal, greenhouse gas reduction, and recycling.

In order to:

- Reduce or eliminate the development or release of pollutants in their activities, employees will utilize green technology and practices.
- Reduce or stop the production of waste materials. Reduce greenhouse gas emissions.
- Gather, put to good use, recycle, or compost garbage.

In order to:

• Reduce or eliminate the development or release of pollutants in their activities, employees will utilize green technology and practices.

- Reduce or stop the production of waste materials.
- Reduce greenhouse gas emissions.

• Gather, put to good use, recycle, or compost garbage.

D. **Natural resources conservation.**

Workers will use specific technologies and methods to safeguard natural resources, such as those used in organic agriculture, land management, and the conservation of soil, water, or wildlife.

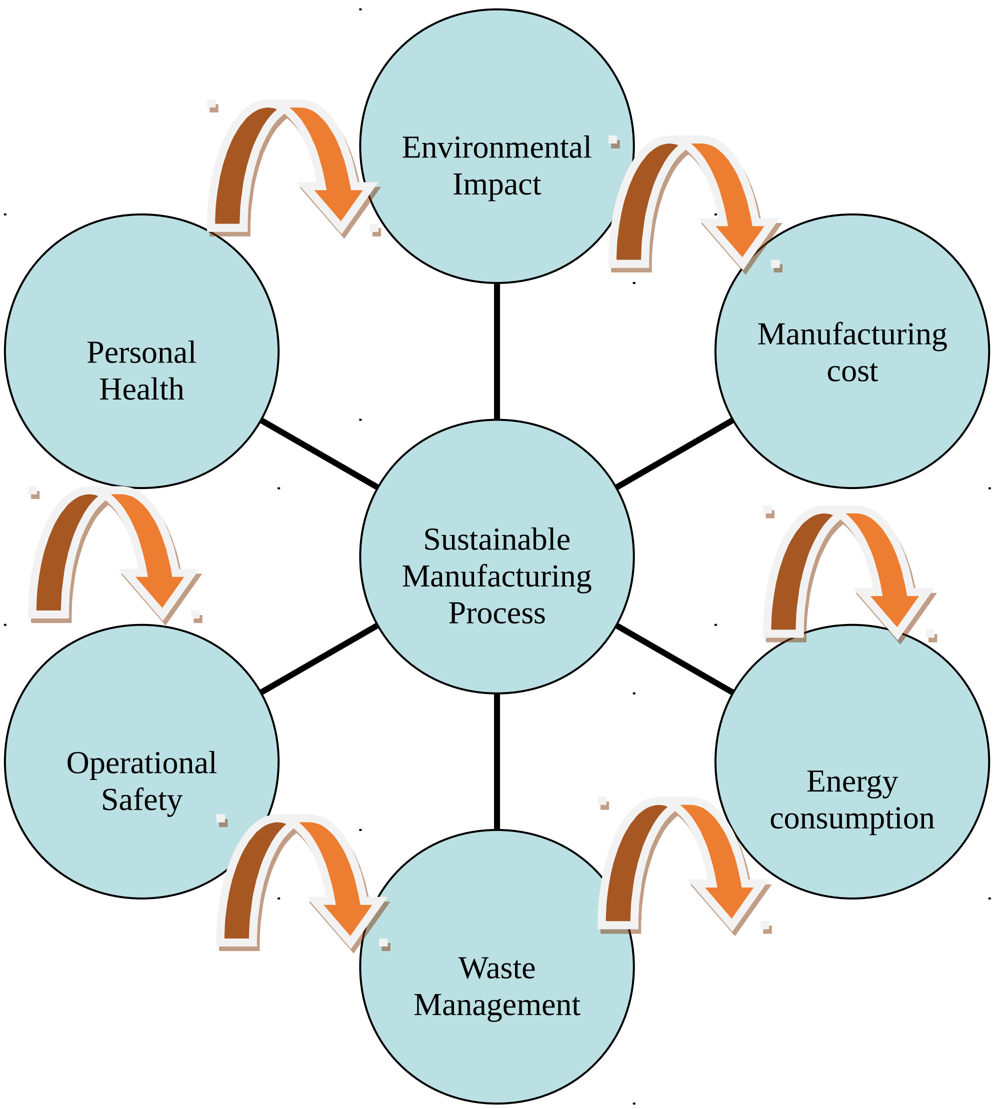

Figure 1: Sustainable manufacturing process

VII. Recycling Techniques

Recycling is the process of turning trash into new products and materials. The capacity of a substance to regain the qualities it had in its initial state determines how recyclable it is. It is an alternate method of disposing of waste to the "conventional" method that can assist conserve resources and reduce greenhouse gas emissions. Recycling can cut down on the consumption of fresh raw materials and the disposal of potentially valuable items, which reduces energy use, air pollution from incineration, and water pollution from landfilling. The "Reduce, Reuse, and Recycle" waste hierarchy includes recycling as the third step, which is a crucial part of contemporary trash reduction. By switching out raw material inputs and rerouting waste outputs away from the economic system, recycling strives to achieve environmental sustainability.

A. **Plastic recycling**

Recovering discarded or wasted plastic and turning it again into useable products—sometimes in radically different forms from their initial state—is known as recycling plastic. This might entail melting down soft drink bottles and casting them as plastic chairs and tables, for instance. A piece of plastic can only be recycled a certain number of times before losing enough quality to be unusable for some forms of plastic.

B. **Physical recycling**

Some plastics are remelted to create new plastic products; for instance, polyester made from PET water bottles can be used to make apparel. This form of recycling has the drawback of causing the polymer's molecular weight to shift more and the concentration of undesirable chemicals in the plastic to rise with each remelt. In the latter part of 2019, a recycling facility made for profit was delivered to the International Space Station. The facility physically transforms plastic scrap and unused plastic parts into spools of feedstock for the space station additive manufacturing facility, which is utilized for in-space 3D printing.

C. **Chemical recycling**

Some polymers can be broken down into monomers once again; for instance, PET can be broken down into dialkyl terephthalate by being treated with an alcohol and a catalyst. The pure polymer can be reused by combining the terephthalate diester with ethylene glycol to create a fresh polyester polymer.

D. **Waste plastic pyrolysis to fuel oil**

Another method entails the heat depolymerization of various polymers, which is a considerably less exact method, to turn them into petroleum. Any polymer or mixture of polymers might be accepted by such a process, including thermoset materials like vulcanized rubber tires and the biopolymers found in feathers and other agricultural waste. The manufactured compounds can be utilized as fuels or as feedstock, just as natural petroleum. Similar to recycling, gasification does not produce polymers, hence it is not considered to constitute recycling. Plastic waste streams, like plastics, can be pyrolyzed to produce high-quality fuels, or carbons.

E. **Waste Paper and Cardboard**

Examples of cardboard and paper include waste cardboard, corrugated containers, old boxes and sheets, and paper products like newsprint and periodicals. The fundamental rule for recycling cardboard and paper is that the material should be as free of contaminants as possible, delivered with a moisture level of not more than 10% air dried weight naturally existing level, and typically required baled, ideally in one specific grade. Nevertheless, loose material can occasionally be accommodated and is always subject to a successful sample load or consignment.

F. **Storage**

Paper and cardboard are best kept indoors to prevent accumulation of rainwater when kept outdoors. However, using a skip or sheet that is contained might make external storage easier. They should always be kept clean and away from dust, oil, and other contaminates when being stored on hard surfaces. Cardboard or paper in skips will prevent excessive contamination if the storage area has a poor surface.

When pallets or other storage containers are utilized, the supplier should be aware that their weights will be subtracted from the loads, and the additional handling demands for the reprocessor may reduce the value of the items in some markets.

VIII. Metal Recycling

All grades of non-ferrous and ferrous metal are recyclable for future use. Because metals don’t lose quality when recycled.

Steps of Metal Recycling:

1) **Collection**
   - This is the first and most important step in the recycling of metal. Simply collect everything that contains metal.
   - This procedure needs to be set up so that there are containers made just for collecting metals.
2) Sorting

XI. Sorting the metals is a crucial next step after collection of the metals. This entails separating recyclable materials from non-recyclable materials.

XII. It is crucial to emphasize how significant the quality of recycled metal is.

XIII. Processing

- After sorting, the metal must then be compressed or squeezed.
- Machines are used to crush and squash all of the recycled materials, reducing the amount of space they take up on the conveyor belts.

Shredding

• The shredding process begins once the metal has been broken and crushed.
• To facilitate further processing, the metals are cut into minuscule pieces or sheets.
• Normally, steel is transformed into steel blocks while, on the other hand, aluminum is transformed into sheets because small bits have a big surface to volume ratio and can be melted using less energy than when they are in huge pieces of metal.

3) **Melting and Purification**

- The scrap metal is melted in a huge furnace.
- Depending on its unique qualities, each metal is brought to a furnace created specifically to melt it. A significant quantity of energy is used during the melting process. The energy needed to melt recycled metal is, however, less than the energy needed to produce metal from its raw materials.
- **Purification**
- The purifying procedure is the following stage after the melting procedure. Different processes are used to purify metals.
- Metals must be purified to guarantee that the final product is high-quality and free of contaminants.
- Electrolysis is one technique for cleaning metals.
- To separate metals from other recyclables, strong magnetic systems are simply passed over other metals. Depending on the type of metal, there are many purifying techniques available today.
- ***Melting and Solidifying of the Metal***

- The molten metal is transported by conveyor belt to a cooling chamber where it is cooled and solidified following the purifying process.
- At this point, the scrap metal has been transformed into a solid metal that may be used once more.
- The molten metal is then given further chemical additions to give it density and other qualities.

8. Transportation of the Metal Bars

- After the bars are planned and created, the finished product is packaged according to their sizes and forms in order to be transported to various factories and to persons who need the metal. After that, the cycle starts over.

IX. WEEE Recycling (Electronic Devices)

WEEE recycling refers to the recycling of discarded electrical and electronic equipment, which includes practically everything that is powered by a battery or socket, including TVs, laptops, and mobile phones.

• The garbage and recycling sector has a specialized division called electronic goods recycling that works to keep electrical devices out of landfills.

• Municipal recycling facilities and some retailers take used electrical and electronic equipment. After that, it is transported to a recycling facility where it is shred into small pieces.

Once shredded:

- Powerful magnets may remove ferrous metals like steel.
- Electronic currents are used to remove additional non-metallic metals.

Plastic is sorted into types by using various methods such as:

- near infrared light
- density separation.

Use of waste electrical items

Electrical products are made up of a variety of pieces that can be recycled and then used in a number of new ways. Examples of what some of the recycled components might become are given below:

Hover mowers contain

Acryliconitrile butadiene styrene, or ABS, is a sturdy plastic that can be used to mold light, rigid items like musical instruments, boxes, pipe fittings, and automobile bumpers.

In new electronic devices like refrigerators, vacuum cleaners, tools, toys, and motors, copper motors are used as winding wire. Copper motors can also be converted into copper pipe, coins in some currencies, jewelry, and wire.

Copper can be mixed with zinc to make brass, or with tin to make bronze.

Games consoles contain

• Steel that can be utilized for beams, automobile parts, and computer cases

• circuit boards, which contain a variety of precious metals like gold, silver, platinum, and palladium; platinum and palladium are utilized in jewelry, mobile phones, catalytic converters, and other products.

Mobile phones contain

- Precious and semiprecious metals including gold, platinum, and palladium, many of which can be recycled into electrical connections and component plating; palladium is essential to the fuel cell technology.
- Batteries can also be used to extract metal.
- Zinc, which is used to galvanize steel and can be included into brass by combining it with copper. Blocks made of zinc are used by ships and submarines to prevent rusting.
- For usage in mouldings, this plastic can be granulated and reformed.
- Priceless components that can be recovered and degraded, like flash memory devices.
- practical components that can be reused, such as aerials, battery connectors, PCBs, connectors, including PCBs with gold-coated edge contacts, keyboards, LCD panels, lenses, and microphones

Figure 2: Electrical waste recycle

X. Wood Recycling

Due to its many diverse uses, wood is the ultimate renewable resource. Wood can be recycled into mulch for landscaping or used again as a building ingredient. Because we can utilize even low-grade wood as fuel to produce environmentally beneficial energy, it is still useful. Typically, recycling plants for wood and timber waste are divided up for processing. The pieces are then placed inside a strong wood shredder, which uses several different procedures to shred them. The vibrating screener does a good job of separating the items despite the fact that their sizes vary. Different uses are applied to findings of various sizes. The fine material is utilized as animal bedding, and the bigger pieces are recycled. The larger of the two sizes is employed in broad.

REFERENCES

[1] Anastasiia Moldavska and Torgeir Welo, "The Concept of Sustainable Manufacturing and its Definitions: A content-analysis based literature review," Journal of cleaner production, vol. 166, pp. 744-755, November 2017.

[2] K.D Ganvir, J.V. Chopade, N.D. Pachkawade, "Green Manufacturing Index Applicability, An Approach to Acquire Industrial Gain", Journal of Physics: Conference Series, 2020.

[3] Cong Quoc Tran and Do Ngoc Hein, "Sustainability Assessment System for Small and Medium Manufacturing Firms - A case study", The International Conference on Logistics and Industrial Engineering, August 2017.

[4] Marco Taisch, Vahid Sadr, Gökan May & Bojan Stahl, "Sustainability Assessment Tools – State of Research and Gap Analysis", International conference on Advances on production Management system, pp 426–434, 2013.

[5] Sabit Shaikholla, Dinara Dikhanbayeva, Essam Shehab and Ali Turkyilmaz, Industry 4.0: Clustering of concepts and characteristics, 21 Feb 2022

[6] Fengwei Yang and Sai Gu, "Industry 4.0, a revolution that requires technology and national strategies", Complex & Intelligent Systems, pp 1311-1325, 27 January 2021.

[7] I.D. Paul, G.P. Bhole, J.R. Chaudhari, "A Review on Green Manufacturing: It's Important, Methodology and its Application", Procedia Materials Science, volume 6, Pages 1644-1649, 2014.