Review on Green Manufacturing: Importance, Methodologies, Implications and Applications

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Abstract: - This paper gives a review on 'Green Manufacturing' where it focuses on different principal aspects upon why we require its incorporation, the various methodologies that can reduce the waste and pollution to a large extent. This paper also focuses on the root from where this concept emerges and how it can lead to energy conservation, development of a new product with less wastage, capable of being sustainable, able to reuse all under short life cycle terms. The implications of industries trying to embrace such a technology, the current and future applications that can be built upon this technology and its potentialities in various sectors are also covered. The main objective of the green manufacturing is to reduce the harmful impact on the environment and to minimize the cost of the product.

Keywords: - Green manufacturing, reduce waste and pollution, sustainability, industrial implications.

I. INTRODUCTION

The term 'Green Manufacturing' refers to revolutionizing the production processes and the establishment of eco-friendly operations within the manufacturing field. This concept emphasizes the workers to use fewer natural resources, reduce pollution and waste, recycle and reuse materials, and minimize emissions in their processes along with those inbound mechanisms that create the products. Green manufacturers research, develop, or utilize technologies, incorporate interdisciplinary methods and practices to lessen the harmful impact on the environment [1]. Not only does green manufacturing benefit the environment, but both existing large firms and new start-ups are equally striving to adopt such eco-friendly methods where reducing the cost of the product is prominent and they are also able to impress their customers to a greater extent which in turn contributes to the profitable benefit of the business. Green manufacturing has also become a vehicle for long-term job creation in the United States. According to a recent Quality Magazine article, green manufacturing currently accounts for 26 percent of all clean energy jobs. What's more, clean and green manufacturing created 35,382 jobs between the years 2003 and 2010 while the rest of the industry shed in numbers. Because of their specialized skills base, clean economy workers earn 13 percent higher salaries than other workers of the U.S. economy. Green manufacturing jobs require a strong core skillset and an added layer of green knowledge [2]. The term is also used to describe sustainable energy generation technologies such as photovoltaic, wind turbines, bioreactors, bio filtration, bio remediation, desalination etc. We don't always have time, or take time, to learn more, read fine print, decipher complex ingredients, and seek alternatives. The word "natural" has become an over-used and inaccurately-used buzzword in today's marketing; it's practically lost all value [3].

II. IMPORTANCE

This concept of Green Manufacturing was not brought about or is in demand to be adopted by so many firms or that extensive research is being done just for the sake of doing it. Over many decades we have witnessed what technology could do to ease our lives, error and rectification over and over again has been the most inevitable duo that has helped us to overcome so many hurdles in designing and manufacturing a product and that this processes still continues to exist trying to find and resolve any issues with the existing trend of the product. However, what we failed to notice was the harmful side effects and unnecessary wastage that occurred during manufacturing or even designing for that matter and hence evolved such a revolutionizing concept.

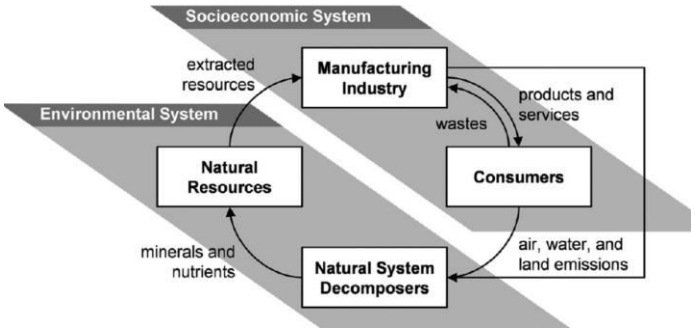

Fig. 1 The role of the manufacturing industry in a sustainable system David A. Dornfeld. et.al.,(2013).

Green Manufacturing, it might sound weird, does include the designing stage. The initial phase of any product to materialize begins with the design and material selection of the product even before we start thing about the functionalities of that product. In olden days, pen and paper are the source to first create a rough draft of the product. By doing so we not only waste the natural resource we also waste the most invaluable time. Indirectly, adoption of Green technologies saves not only the environment and helps sour business but can also fulfil the most basic need of the customer which is early and periodic dispatch of products in the market along with the required features and functions, which is separately compiled under the term 'Agile Manufacturing'.

III. METHODOLOGIES

A) Sustainable Management Tools

The tool generally used is the Life Cycle Assessment (LCA) [4]. It is an approach to examine fully the environmental impact of different activities performed by humans including the production of goods and services by corporations. LCA can be applied for any activity that is either at national level or global level in order to identify environmental burdens resulting from the activities of a society, region or industrial sector. In fact, LCA can provide an excellent insight for the engineer to study any given product such that he/she can identify the methods to reduce the environmental impact of a specific product or process. A schematic of the methodology employed for carrying out the LCA is given in Fig 2.

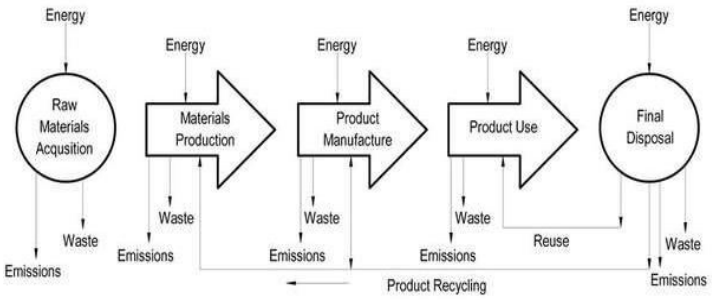

Fig. 2 Life Cycle Analysis

LCA is concerned with identifying the environmental impact of a given product or process at each of these life stages. Full implementation of LCA allows the engineer to make a quantitative comparison of the stages of a product's life, determine where the greatest environmental benefit is to be gained, and ultimately monitor the long term effect of changes in design and/or manufacturing. LCA is concerned with identifying the environmental impact of a given product or process at each of these life stages. Full implementation of LCA allows the engineer to make a quantitative comparison of the stages of a product's life, determine where the greatest environmental benefit is to be gained, and ultimately monitor the

long term effect of changes in design and/or manufacturing. The ISO standards assume a process based LCA approach and is organized into four steps: goal and scope definition, inventory analysis, impact assessment, and interpretation as shown in Fig 3.

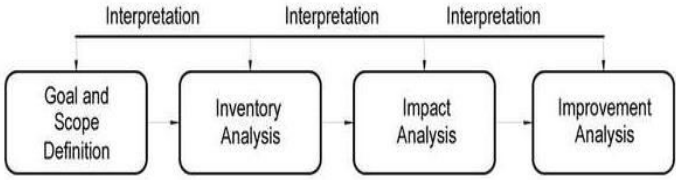

Fig.3 Framework Of Life Cycle Analysis

B) Resource Environment Protection

The upgrading of manufacturing industry to green manufacturing needs to be based on the total factors innovation, in order to achieve the green transformation of traditional manufacturing and the green development of new manufacturing. Innovation system is a system which promotes economic development by combining several elements of interaction and interdependence. It is the key to realize green manufacturing. According to the factors, the green manufacturing innovation system based on resource environment protection can be divided into two categories: the green transformation of traditional manufacturing industry and the green development of new manufacturing industry. The factors of green transformation in traditional manufacturing industry refer to single factors, such as labor, capital, resources, etc. [5]

C) Supply Chain Sustainability Report (2020)

The MIT Centre For Transportation And Logistics in association with Council Of Supply chain Management Professionals did perform a survey on Supply Chain sustainability [6] whereby the research approach has three pillars: an anonymous survey of supply chain professionals, cross-industry executive interviews, and a systematic review of media coverage and corporate social responsibility reports. Such techniques was made deliberately so that the resulting report meets demands for information on supply chain sustainability that are not being met by current past research in this area. The survey was taken over a sample of 1100 Supply Chain professionals.

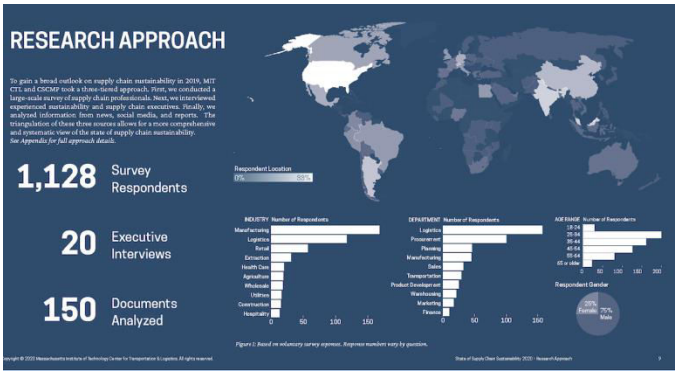

Fig.4 MIT SSC Report Insight

Selected Report Insights:

* The pressure to drive supply chain sustainability is diffuse across many sources, and contrary to accepted wisdom, it is being exerted by a diversity of stakeholders—not just campaigners like non-governmental organizations (NGOs).

* There are clear differences across industries in commitment, investment, and approach, but common threads exist with what goals organizations are setting and how they are attempting to reach those goals.

* The role of the supply chain professional in sustainability is clear. For many, professionals and executives alike see sustainability more commonly as a part of supply chain duties.

* With frontline laborers taking a brunt of the pressure for supply chain management during COVID 19, a poll in April 2020 showed that managers and executives alike see social sustainability as top of

mind as we head into 2021.COVID 19 is a litmus test for company adoption of supply chain sustainability.

IV. IMPLICATIONS

The adoption of Green or Sustainable techniques is no longer something that's considered nice to do; it has become a must-do in all levels of an industry. Cutting costs and reduction in waste might be a most valuable and inevitable outcome but beyond that it has now become a center of attraction for people and the business people use such techniques as a leverage to commercialize their products based on the methods of how it was produced. In a recent study [7] conducted by The MIT Center for Transportation & Logistics (MIT CTL) and the Council of Supply Chain Management Professionals (CSCMP), 46% (n=701) of the 1,128 survey respondents noted they felt pressured by external stakeholders to adopt sustainability practices. With this pressure, stakeholders also want transparency of the practices outside of traditional press releases. By capturing sustainability practices within an organization's enterprise applications, leaders are able to validate current state processes as in Fig 5.

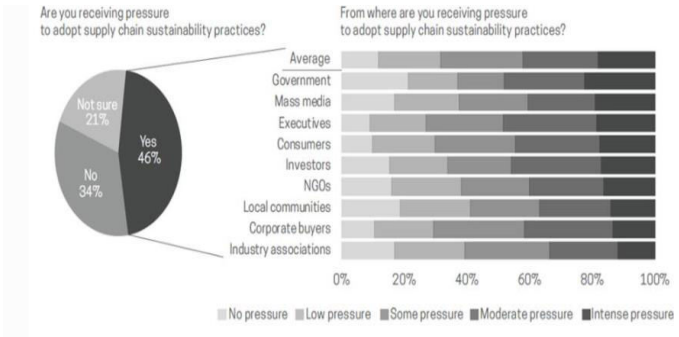

Fig.5 State of Supply Chain Sustainability Report – 2020

Every organization needs to prepare for the imminent as well as unexpected changes of operating in a fast-changing global business environment. As is the case of Joe Biden [8] who pledged to re-join the Paris Climate Agreement, along with a $1.7 trillion plan to invest in clean energy infrastructure of the next 10 years, the method to track and trace the implementation of these activities within organizations will be integral to measuring the impact. It is also important to note that these analytics and metrics within an enterprise application must be able to scale as the new administration looks to fast-track sustainability efforts, as well as realize the impact of government support for sustainability.

The increased expectation of 'voluntary sustainability reporting' is yet another major indirect implication of adopting Green Manufacturing techniques, it can be greatly used to seek global attention to become a manufacturing hub. As is the scenario in countries such as India, Indonesia and China by mandating the reporting of sustainable practices, however the reporting of sustainable practices continues to be voluntary in the United States and that's the reason why US lags in the filed of production or so as to say in the hardware sector. With KPMG [9] reporting that 93% of the 250 largest global organizations now publish sustainability practices, stakeholders will look for small and medium enterprises to begin publishing these reports as well. By incorporating sustainability reporting standards such as the Global Reporting Initiative (GRI) framework into an organization's digital transformation strategy, leaders of large, medium and small enterprises could be able to map information and metrics from enterprise applications into sustainability reporting templates. A clear statistical report is as shown in Fig 6.

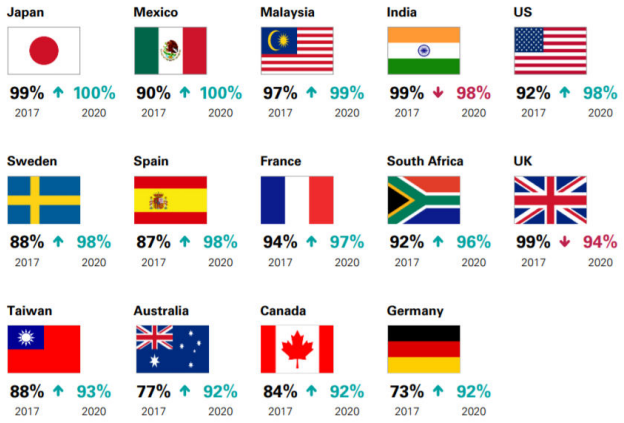

Fig. 6 KPMG Survey of Sustainability Reporting 2020

V. APPLICATIONS

A) AI, ML, IoT and Automation

Newer manufacturing solutions are making supply chains smarter, faster, more customer centric, and more sustainable [10]. This includes the growing integration of Artificial Intelligence (AI) and Machine Learning (ML) techniques and harnessing the power of big data to cultivate more agile supply chains to the adoption of eco-friendly production and packaging materials which could also boost the efficiency within and beyond the supply chain practices. Also, the incorporation of such interdisciplinary practices such as AI and ML provides enterprises to forecast more accurately and practices like Internet of Things (IoT) and Automation prevent real time wastage reduction and large scale completion of activities in shorter time periods. In terms of sustainability, the fact that this data can be analyzed quickly to implement swift resolutions that can have an immediate impact on reducing an organization's carbon footprint could make achieving sustainable manufacturing far quicker and easier.

B) The Adoption of a Circular Economy

As consumer and company awareness of environmental concerns continues to grow, many companies are shifting their existing take, make and throw away model for a circular economy alternative that aims to reuse, reduce, and recycle within the supply chain model. A large portion of this shift is driven by growing government and social pressures to minimize and limit the use and production of single-use plastics, which is enforced not only by consumer values but also through bans. However there are other advantages to implementing a circular economy that is, by reusing, reducing and recycling within the production chain, the use of materials can be utilized effectively. This trend is still in its baby steps but it's likely we'll see more companies starting to favor the use of eco-friendly packaging solutions and recycled materials for product manufacturing over conventional practices. The result is not only a more eco-friendly business model, but in some cases means a more secure business as a whole, as companies will be less affected and reliant on raw materials and natural resources that could be impacted through climate change.

C) Sustainable Logistics

Transportation, both within the plant and between plant and resource collection area, plays a huge part in the functionality of manufacturing supply chains. However, sustainable shipping is becoming increasingly prevalent throughout the supply chain, working towards reducing transportation emissions that can be harmful to the environment, as well as a business's bottom line if they don't adhere to government regulations. With this in mind, there's a definite shift towards finding more sustainable means for shipping goods from A to B, which include using locally sourced suppliers to help reduce transportation mileage. Other areas that are under the spotlight include optimizing shipping containers to use all the space to transport full loads rather than doing multiple shipments of half-filled containers.

D) Fuel & Nature Conservation

Fuel is the major issue in the world [11], the fuel used in our day-to-day life is non-renewable and it will become non-existent and hence there is a requirement for alternate source. The only hope is renewable energy sources like solar, wind, tidal, biodiesel etc. Therefore sustainable energy can be used as fuel. Water

purification is the another issue as it is our most important need but due to population and due to untreated industrial discharge into fresh water bodies, the water becomes toxic. The solar distillation process is very useful for the water purification process. Air purification, plants could be grown indoors to keep air fresh because most of the common plants remove CO_2 and convert it into O_2. Due to this the adaption, inhalation of contaminated air contaminated air could be reduced. Sewage treatment is conceptually similar to water purification. Solid waste management is the purification, consumption, reuse, disposal and treatment of solid waste that is undertaken by the government or the ruling bodies of a city/town. Energy conservation is the utilization of devices that require smaller amounts of energy in order to reduce the consumption of electricity. Reducing the use of electricity causes fewer fossil fuels to be burned to provide that electricity.

VI. CONCLUSION

While it's impossible to transform our manufacturing operations overnight, the common hope is to strive everyday towards that goal focusing only upon the merits of implementing them for the betterment of oneself and the environment as a whole. Sustainable manufacturing is the most important aspect to be considered by all production engineers, not because it is a fad but a necessity as an obligation to the world we live in. Product life cycle analysis has become a tool of choice being used to establish the environmental impact of the products that we produce. Though application of PLA is time and data intensive, provides very clear avenues where engineers will be able to reduce the environmental impact. There are a number of areas within manufacturing that can be benefitted greatly by the adoption of green manufacturing practices. The three major principles to be considered are to reduce the resource utilization in the process, use environment-friendly materials, reduce all forms of waste and reuse and recycle as much material as possible to realize the goal of self-recovery capability of the earth.

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