Industry 4.0 transformation initiatives in a small scale mill board unit through sustainable manufacturing: A case study

R Vezhavendhan¹, S Senthil Kumar², K Jayakrishna³ and S Aravindraj⁴

¹ School of Mechanical Engineering, Vellore Institute of Technology, Vellore, India, vezhavendhan.r@vit.ac.in
² School of Mechanical Engineering, Vellore Institute of Technology, Vellore, India, ssenthilkumar@vit.ac.in
³ School of Mechanical Engineering, Vellore Institute of Technology, India, jayakrishna.k@vit.ac.in
⁴ School of Mechanical Engineering, Vellore Institute of Technology, aravindraj.s@vit.ac.in

Abstract: Small scale mill board manufacturing industries are shutting down shop at an enormous pace. Observation shows that three out of five such units close down operations within three years of its inception due to their inability to sustain in the market. These units have not been able to utilize resources effectively and have not been able to run profitably too. Further, they have been struggling to meet the norms stipulated by the state pollution control board. This article is a review of various problems identified in a mill board unit and the measures taken that made the unit self-reliant and transform into an Industry 4.0 enterprise through sustainable smart manufacturing concepts. This case study describes measures adopted to revive a struggling mill board unit and its success in terms of economic profitability and issues in incorporating Industry 4.0 concepts.

1. Introduction

Mill board is the technical name for boards made out of recycled waste paper. All small mill board industries aim at making profits and few are good at it too, while many are not. Along with fulfilling this aim lies the responsibility of every industry to fulfill their aims and goals in a responsible way by not dumping trash on this planet. Recycling industries are much prone to such activities of dumping trash as they are industries that receive lot of unwanted trash along with the ones that they are capable of handling and processing. A part of the wastes coming in are either unwanted or not capable of being processed by them. Hence these end up in landfills in surrounding areas resulting in environmental pollution. Apart from these many wastes are generated during the reprocessing of the wastes itself and there needs to be a green initiative to take care of all the wastes generated in the industries through sustainable manufacturing practices. Moreover industries are faced with challenges such as depleting resources and pollution of environment leading to heavy competition along with regulatory pressure from Government agencies to curb pollution and improve their carbon footprint points and sustainable manufacturing practices pave the way to beat all the above. To identify possible areas to implement various sustainable manufacturing practices in a Mill board manufacturing unit and transform it into a sustainable enterprise. And to present a case study of implementation of sustainable manufacturing practices to transform a mill board unit

2. Literature Review

There have been several adverse effects created by industries over the last few years leading to severe pollution of the environment and depletion of resources due to over use and abuse. Sustainability in manufacturing, which is defined as a philosophy of manufacturing by “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [1] is the best way to tackle the situation. Sustainable manufacturing which can be defined as a method to develop technologies to transform materials without emitting much greenhouse gases, using non-renewable or
materials that are toxic in nature or waste generation [2] paves the way for reduced environmental pollution and effective use and reuse of materials and raw materials. Industries need to understand that it is very important for a manufacturing organization to be economically viable for survival and the possibility to sustain the enterprise may not be bright in the long run when damages caused to the ecosystem are irreversible through the emission of greenhouse gases (GHG) and wastes that are toxic and non-renewable resources that are depleting [3]. Economic profitability is a representation of sustainability. And sustainability is also a form of duty and a responsibility towards all the environmental, social, and economic indicators, which are known as the triple bottom line of sustainability [4]. In order for sustainable manufacturing to be achieved, major changes are needed to have a thrust towards industrial processes that are more sustainable [5]. Sustainable manufacturing has a general principle to reduce materials use intensity, consumption of energy, emissions, and unwanted creation of by-products while maintaining and improving products of value to both the society as well as to the organizations [6].

- Some of objectives of a sustainable manufacturing system can be,
- Resource efficiency improvement and management of waste
- Product life cycle examination involved in manufacturing.
- Minimizing pollution of environment while ensuring economic growth
- Examining how to stimulate innovation and investment to provide cleaner technology
- Provision of employee awareness and training [7].

One of the recent trends in the segment of manufacturing is the concept of Industry 4.0 which is seen as a thing of importance among small enterprises to face competition through the use of new and innovative production and management technologies. Industry 4.0 has significant effects through the application of advanced and latest technologies, big data architecture creation and data analysis. Through the use of proper and cost effective information technology application in manufacturing, the small and medium enterprises (SMEs) can expect to have a significant increase and influence on the orders that they receive [8]. Shrouf et al. [9] have carried out a study on the concepts of Industry 4.0. in detail. The present enterprises were checked for the necessary infrastructures that are specified in the Industry 4.0 transformation process. Stock and Seliger [10] highlighted Industry 4.0 opportunities for sustainable manufacturing and production and the growth in demand for consumer goods and the limitations involved in meeting those demands.

3. Case Study

Sustainable manufacturing initiatives were carried out in a mill board unit situated in Vellore district of Tamil Nadu, India. The unit is a small scale unit with a turnover less than USD 50,000.00 per annum. The unit was established in the year 2008 and has been functioning since then catering to customers from several domains such as stationery, industrial packaging, textile manufacturers and other packaging areas etc. The unit was making low profits despite being in the field for a little over a decade. Hence the management started looking out for pertinent ways of improving its profitability some way or the other. After a lot of efforts and consultation it had decided to try its luck with the help of the concept of Sustainable Manufacturing. The plant embarked on the project of implementing sustainable manufacturing practices in the month of February 2019. The unit had picked up a few initiatives of sustainable manufacturing and only the major initiatives among them are discussed here along with the benefits reaped through them.

In order to take up sustainable manufacturing initiatives and implement it, a team that could take up and implement sustainable practices was created. There needed to be a thorough understanding of the process of manufacture of mill board. Hence the process was studied and a process map was created. The process needed to be evaluated to identify areas where sustainable manufacturing could be implemented. A brainstorming session had to take place for evaluation and identification. The whole organization was asked to submit their suggestions and solutions and it was informed that the best suggestions and solutions would be awarded. This acted as a catalyst for the employees to involve themselves in the activity. Once the suggestions and solutions were collected, they were reviewed and
evaluated for suitability and possibility of implementation along with that of the team. The relevant and best solutions and suggestions were implemented. Data on improvements made and wastes eliminated was collected and compared to understand the economics of implementation of sustainable manufacturing practices. The roadmap of the implementation process is given as under in Figure-1 and The process map of the mill board manufacturing process was mapped and the process map is given below in Figure 2.

![Figure 1. Implementation roadmap](image1)

![Figure 2. Process map of mill board manufacturing](image2)
4. Initiatives Taken

Given below is a list of initiatives taken

4.1 Initiative I

In due course, the team identified that there was a need of 10 kilo litres of water on a daily basis of which around 4 kilo litres was lost due to absorption during the pulping and board formation process and around 2 to 3 kilo litres of water was lost due to evaporation during the board drying process. At the end of the day, the remaining water ranging between 3 to 4 kilo litres was pumped to the Effluent Treatment Plant (ETP) for processing and the treated water was used for gardening purposes.

The process was modified wherein a tank which was called as the recycling tank was included in between so that the water coming out after the board making process could be collected in the recycling tank and reused by adding the water to waste paper (raw Material) for pulping the next day as shown in figure-3 below. This resulted in the following benefits

- Reuse of 3 to 4 kilo litres of water thereby saving water intake of 18 to 20 kilo litres per week (Approximate savings of 108,000 litres to 120,000 litres per month).
- Reduced use of ETP form daily use to usage of once in a week only to treat the same amount of water which came out in a day.
- Reduced usage of a 3 HP electric motor and connected pump only once in a week instead being used daily

![Figure 3. Modification in the process](image)

4.2 Initiative II

It was found that a large amount of raw materials consisted of plastic laminations over them which ended up as remnants of the filtrate of the paper pulp. This usually was removed from the pulping machine and ended up in landfills causing huge environmental problems. Along with this plastic generated, raw material supplies received consisted of mixed plastic wastes accompanying the paper wastes which also found its way to landfills. Hence it was decided to check what could be done about this and how it could be done. Hence with the help of a chemical engineering expert a small pyrolysis plant with a capacity to process 200 kgs per day was set up as an initial phase. This resulted in approximately 80 litres of fuel per day, and the residue was converted into manure adding to the revenue of the enterprise.

4.3 Initiative III

The standard size of boards produced for daily calendars backs were 27 x 31 inches this resulted in 5 calendar backs from each board. The result was that there was a large scrap generation of about 600 grams on an average from each board. After a thorough study and brainstorming it was decide to
increase the size of the board to 30 x 34 inches and this resulted in retrieval of 6 calendar backs instead of the regular 5 numbers. Further the scrap generated from each board came down from 600 grams per board to just 150 grams per board. This also resulted in better utilization of resources, material and increased profitability to both the supplier and the customers.

4.4 Initiative IV

Analysis of the propulsion forces of Industry 4.0 to be adopted by small enterprises. By analysing the difficulties in transition process of small enterprises to Industry 4.0, it was understood that enterprise support is required in the determination of strategic steps to facilitate the transition of enterprises to Industry 4.0 and make improvement towards efficient use of resources.

For the Industry 4.0 transformation the things taken into deliberation were comparative advantages, relevance, support from management, size of the organizational, expertise available in information technology, complexity, pressure from competitors and external support. It was concluded that Cost criteria, intelligibility, distrust of benefits, transition expenses, maintenance costs, technical support, training costs, recognition and support cost criteria are to be determined according to expert opinions.

![Figure 4. Architecture of Industry 4.0 transformation](image1)

**Figure 5. Framework of Industry 4.0 transformation for small enterprise**

5. Conclusion

The sustainable manufacturing initiatives lent a helping hand to the mill board manufacturing unit in terms of saved resources, better utilization of resources and many more whose list is given below along with the economic savings. The benefits reaped are listed below

- Better utilization of existing resources
- Increased profitability for the unit
- Possibility of setting up a larger pyrolysis plant in the near future
- Increased customer satisfaction
• Decreased scrap production
• Savings in terms of electricity
• Water savings to a huge extent and
• Reduced (by almost 85%) environmental pollution
• Less strain on the ETP and hence longer machine/equipment life
• Increased employee morale

After the implementation of sustainable manufacturing initiatives, today the unit stands as a profitable, satisfied and transformed unit as a result of enterprise transformation through sustainable manufacturing initiatives. The implementation of Industry 4.0 was a challenging task, which has been initiated at a lower degree and may take over the entire process in future.

6. References

[1] World commission on environment and development (WCED) Our Common Future 1987 Oxford and New York: Oxford University Press, NY.
[2] Allwood J 2009 Sustainable Manufacturing Seminar Series (http://www.ifm.eng.cam.ac.uk/sustainability/seminar/documents/050216lo.pdf).
[3] Sumit G, Dangayach G S, Singh A K, Meena M L and Rao P N 2018 Implementation of sustainable manufacturing practices in Indian manufacturing companies Benchmarking: An Int. J. (https://doi.org/10.1108/BIJ-12-2016-0186)
[4] Elita A and Annike L V 2015 Key Performance Indicators for Sustainable Manufacturing Evaluation in Cement Industry, 12th Global Conf. Sust. Manu.Procedia CIRP 26 pp 19-23.
[5] Abdul R S H, Evans S and Longhurst P 2008 A comparison of four sustainable manufacturing strategies. Int. J. Sust.Eng. 1 (3) pp 214–29.
[6] OECD (Organization for Economic Co-operation and Development). Sustainable manufacturing and eco-innovation: towards a green economy 2009, http://www.oecd.org.
[7] Abdeen M O 2008 Energy, Environment and Sustainable Development Renewable and Sustainable Energy Reviews 12 pp 2265-300.
[8] Roblek V, Meško M and Krápež A 2014 A complex view of industry 4.0. Sage Open p 6.
[9] Shrouf F, Ordieres J and Miragliotta G 2014 Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm. Proc. IEEE Int. Conf. Ind. Eng. Eng. Mgmt (Bandar Sunway, Malaysia) pp 697–701.
[10] Stock T and Seliger G 2016 Opportunities of sustainable manufacturing in industry 4.0. Procedia CIRP 40 536–541.