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A system model for green manufacturing Based on the Research Database

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ABSTRACT
Regulatory mandates, product stewardship, public perception, and competitive benefits are just some of the reasons stakeholders are pressuring businesses to be more environmentally friendly in their product and process development. Using the U.S. commercial carpeting sector as a case study, this article offers an exploratory analysis of the connections between ecologically sustainable production processes and particular competitive results. Empirical research on the effect of environmental practices in the organization results is often unclear, in part because of methodological flaws in previous studies. This article reviews the whole commercial carpet sector in the United States and attempts to remedy some of the problems that have been identified. Conclusions Environmentally responsible production methods may improve business performance. There is a wide range of competitive outcomes associated with various ecologically friendly manufacturing methods (e.g., pollution avoidance, product stewardship). Management professionals in engineering and operations may find these results useful as they adapt to changing environmental and economic conditions.

Keywords:Carpet Industry, Sustainability, Green Manufacturing, Planning, Control, Environment.

I. INTRODUCTION

There has been a resurgence of interest in the effects of industry and business on the environment during the last decade. Organizations are being asked or required by authorities, consumers, shareholders, board members, and workers to be more environmentally responsible in their goods and procedures. Reasons for these expectations range from compliance with regulations to product stewardship to improved public perception to the possibility of reaching a larger audience and gaining a competitive edge. Yet, there is a lack of consensus in the literature on the effect of environmental practises on business results. Environmental efforts may have a detrimental effect on corporate performance, according to some studies; yet, other studies have shown that proactive environmental policies may lead to competitive advantages.In the past, empirical studies on corporate environments frequently relied on broad, oversimplified measures, including proxy or scaling variables [13]. When it comes to weighing the relative importance of environmental and competitive factors, practitioners, particularly those at the operations level, have little use for broad and/or aggregated measurements since they give so little information on specific environmental practises. Moreover, traditional empirical research often employed broad financial variables like revenue or profitability as outcomes. There is a school of thought [3] that suggests using broad metrics might lead to equivocal results since it is difficult to get to the real links between environmental interventions and outcomes. Simply said, metrics like sales or profit may be affected by a wide variety of internal and external factors.

This paper adds to the literature by investigating the connections between environmentally friendly production methods (such as cutting down on raw materials, recycling solid waste, and revamping products to be more eco-friendly) and economically advantageous production results (such as lower production costs and higher quality products). This is in line with calls from environmental scientists for additional investigation into the microscopic factors at play in certain interventions. Therefore, operations and engineering managers may more readily use this paper's findings as they prioritise and react to competitive and environmental demands. This study adds to the existing body of knowledge by examining an under-researched sector of the economy that yet plays a crucial role in the promotion of environmentally responsible production practises: the commercial carpet business in the United States. The commercial carpet sector in the United States has a long history of ecological problems, including as excessive resource use, waste from manufacture, and improper disposal of discarded carpet. Furthermore, the majority of the sector is concentrated within a hundred miles of Atlanta, Georgia; hence, manufacturing and disposal techniques impact a sizable population in the surrounding area. Nevertheless, in recent years, the sector has started a significant effort, including the formation of a new industry association, to improve its environmental standards. In 2005, for instance, it was estimated that 4.5 billion pounds of old carpet were destined for landfills in the United States. The target set by the industry group is 23%, thus the amount redirected was about 10%.

1.1 : Is Green Sustainable?

How can you tell the difference between green supply chain management and sustainable manufacturing? The terms "sustainable" and "sustainable" may mean different things depending on context. Something which "meets the requirements of the current without jeopardising the potential of coming generations to fulfil their own needs" is what the Global Commission on Environment and Development calls "sustainable development." [10]. There are two major ideas included in this definition:

- The idea of "needs," with special emphasis on the most basic requirements of the world's impoverished.
- The concept that the capacity of the environment to provide for current and future demands is constrained by the current level of technology and social structure.

Triple bottom line thinking, in which ecological, economic, and social considerations are all equally important, has been linked to sustainability in light of this expanded definition of sustainability's scope to include social analyses. As in Fig. 1.1, this has implications for production. Manufacturing that takes into account the effects on the natural world, the economy, and the community at large is said to be sustainable. Remember the U.S. Department of Commerce's definition of sustainable manufacturing from up above: "try and minimise negative environmental consequences, preserve energy and resources, are safe for workers, communities, and customers, and are economically viable." If a business isn't at least breaking even, it has little chance of survival.

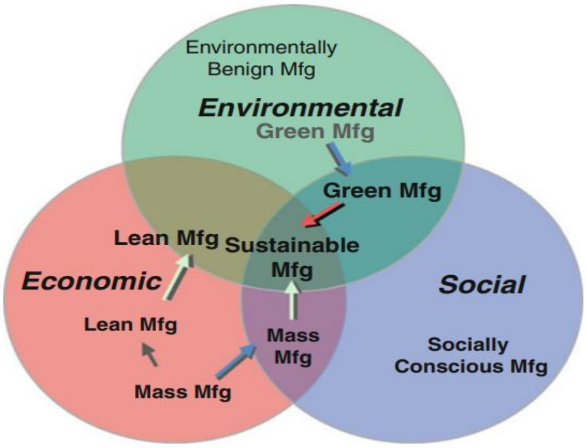

Fig No. 1 : Considering the three tenets of sustainable production

Fair trade legislation and the decline of child labour are only two examples of how the social dimension has become more significant in manufacturing. Hence, this pillar is similarly essential to the success of industrial companies, but it is sometimes the hardest to articulate in terms of practical, manufacturing-related business language. There are a variety of other indicators of a company's social effect, such as the number of workers trained, the average salary, the percentage of employees who stay with the company, the number of workplace injuries, and so on. The last element is environmental, since rising economies and their associated demands for manufacturing have brought about a preexisting problem with emissions of greenhouse gases and resource consumption. Most businesses only succeed in two of the three areas. Yet, being successful in all three areas is not just ideal, but highly challenging. The degree to which a company is meeting the "triple bottom line" is frequently reflected in the CSR reports it posts online.

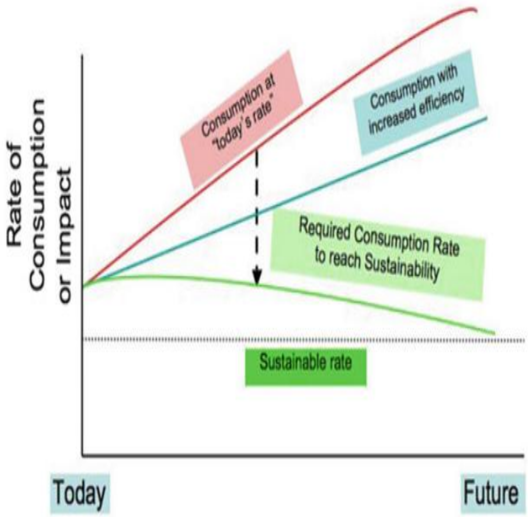

Fig No. 2 : Showing the effects of consumption over time

With the above criteria, we are able to identify what constitutes a steady rate of resource consumption or effect as a result of a process or activity. For instance, the amount of water that may be used sustainably in California depends on the amount of precipitation that falls during the winter and is stored as ground water, as well as the amount of snowpack in the Sierra Nevada that melts during the summer. Water use that exceeds what can be replaced is readily apparent. Similarly, the earth's biosphere can naturally withstand some amount of damage, such as from greenhouse gases. Scientists, policymakers, and other individuals are now debating the safe upper limit of greenhouse gas emissions. As the current pace of consumption (and its influence on the climate) is unsustainable, most scientists conclude that carbon dioxide levels in the atmosphere have already risen to an unsafe level. Little changes that assist lessen usage or impact will have an effect, but they won't be enough to achieve sustainability on their own.

II. PREVIOUS WORK ON ECO-FRIENDLY MANUFACTURING METHODS

Environmental activities have been given a wide range of names by academics throughout the years. Emission controls, prevention of pollution, and product stewardship are some of the terms used to describe various eco-friendly actions [2]. "End of pipe" pollution control refers to measures taken after pollution has already been produced, such as capturing, containing, treating, and/or disposing of it. Filters on smokestacks, designed to catch pollutants before they reach the air, are an example of reducing pollution in action. Pollution prevention is seldom prioritised because of its high price tag and lack of perceived value in terms of competitive advantage [11]. It's more closely linked to just meeting regulations than actively seeking out ways to improve efficiency or reduce waste. To that end, this research examines two strategies: product stewardship and pollution avoidance.

Costs may be reduced or avoided altogether by pollution prevention [11]. Reducing resource use, decreasing waste production, and recycling are all examples of actions that can reduce pollution. Pollution, according to Porter and van der Linde [2], is a sign of squandered resources and lost output. That's why it's so important to develop new products and processes that help cut down on or eliminate pollution altogether.

Product stewardship expands the environmental viewpoint beyond only the production and operations departments to include additional external and internal stakeholders such as research and development, industrial designers, and suppliers [11]. Product stewardship include activities including rethinking production methods to reduce environmental impact, switching to sustainable materials, and pressuring manufacturers to implement pollution-prevention and product-monitoring systems. One way in which companies may benefit from product stewardship is via competitive preemption [14]; for instance, a business might have a leg up on the competition by establishing itself as an industry leader in "green" practises before its rivals. Hart [11] argues that there is reputational "space" in which businesses may gain an edge via improved environmental or green performance. The same holds true for consumers; a company with a solid green reputation is likely to see an increase in sales. Manufacturing quality may be enhanced by product stewardship initiatives including developing goods or production processes to be less harmful to the environment [1].

Environmentally sustainable manufacturing strategies, often known as environmental sustainability in manufacturing, focus on both reducing pollution and responsibly disposing of products. As such, the issue this study seeks to address may be restated as follows: Is there a correlation between pollution avoidance and product stewardship, two examples of environmentally sustainable manufacturing methods, and a number of different competitive outcomes?

III. LITERATURE SURVEY

Environmental manufacturing practices and competitive outcomes have received less attention and fewer studies than the literature on main causes of climate practices [2] and theoretical and case study work on the links between environmental practices and performance metrics [11]. Several empirical research, such as [4], indicate a favorable correlation between environmentally responsible production methods and market position. Chrisman [3] concludes that pollution protection methods do not contribute to cost advantages, but that complementary assets like creativity and early timing are highly connected to cost advantages. For example, [14] cites empirical research that fail to find any beneficial or statistically significant associations between environmentally friendly production methods and competitive results.

However there have been methodological constraints in the empirical studies of environmental industrial practises and competitive outcomes. Financial measurements (profits, sales, revenues) are occasionally used as outcome indicators notwithstanding their disconnection from direct industrial competitiveness outcomes (such as cost) [3]. This was the case in other research that looked at the link between environmentally friendly production methods and competitive results but came up empty [10]. Furthermore, environmental practises are often measured using composite scale variables that include a number of different indicators [3]. Although the methodology may be solid statistically, the practise may lead to conclusions that are too broad to capture the intricacies of different people's environmental habits. Large, diversified samples collected from a variety of industries may further contribute to the lack of consensus [3] since certain sectors may see positive links between environmental policies and competitive results, while others may see negative associations. As will be discussed in the section on how the research was conducted, this work makes an effort to overcome these methodological restrictions.

IV. SYSTEM MODEL FOR GREEN ENERGY

Modeling complex systems helps us better understand such systems, their components, and the relationships between them. As such, the suggested model for a green manufacturing system is meant to aid in our understanding of green supply chain management in terms of:

- Taking into account all the steps needed to determine the industrial system's present degree of environmental friendliness.
- Setting out the green transformation strategy and the numerous instruments and control measures needed for this.
- Detailing how to keep the gains made and keep improving upon them so that the system remains more environmentally friendly.

Figure 3 depicts the simulation model architecture for green manufacturing system design and control. The planning and development processes of green manufacturing systems are described in the first module of the architecture, while the control mechanism that regulates the design and planning mechanism at each level is described in the second module. The strategic goals and restrictions signalled by the top-level decision-makers at each level inform the performance metrics used by the control module. The shown architecture has open information flow in that it may be accessed from any layer, and it has a mixed structure in that it consists of both hierarchical and partitioned layers. In the following sections, we'll break down the architecture into its constituent parts—four distinct levels.

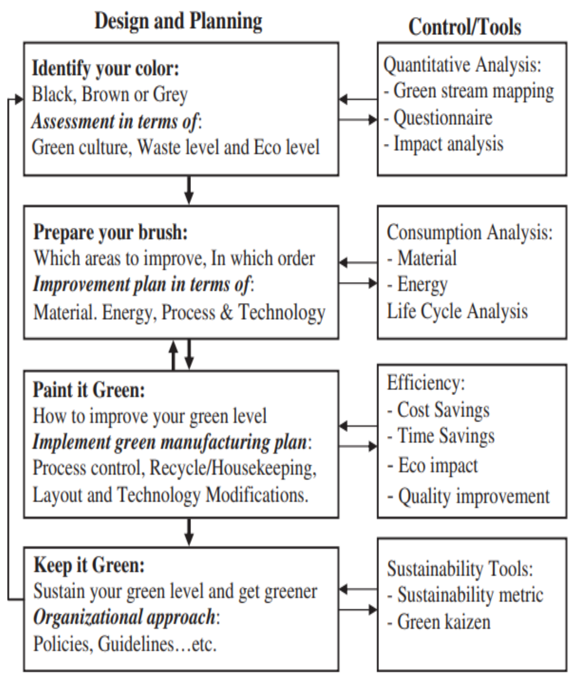

Fig No. 3 - System model for green manufacturing

The first step in any process of reform is always an honest evaluation of the existing state of affairs. This stage of the green industrial planning and design process seeks to quantify the system's degree of eco-friendliness. The greenness of a manufacturing process should be evaluated on several dimensions, from the operational to the system levels. Establishing a quantitative method of evaluation is the current obstacle. Nothing can be improved upon if it is not measured. The manufacturing system will be ranked based on how well it meets industry-specific green manufacturing benchmark objectives and practises, as determined by the quantitative assessment findings colour with respect to green). In the evaluation, non-green systems may be placed in one of three categories: near to green (represented by a grey hue), in the middle of the road to green (brown), or far from green (red) (black in color). As will be shown, each colour should correspond to a certain numerical number. Also, the evaluation results will be utilised as performance measures and improvement objectives throughout the green transformation process.

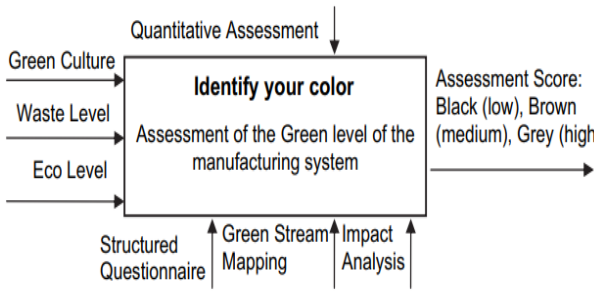

Fig No.4 - IDEF0 model for the assessment layer.

To meet the present requirement for a thorough quantitative evaluation measure, the author proposes and is developing a metric called the green manufacturing metre (G2M). As inputs into a weighted mathematical formulation, the metric will manipulate data collected about the bother wasting level (in terms of materials wasted/not recycled and energy consumed), the eco level (in terms of environment effect and carbon print), and the existing green culture in the manufacturing system (a descriptive measure of workers' environmental performance and awareness activities). Structured surveys, balanced scorecard, impact analysis, and green stream mapping (or GSM), which is a variation on the value stream mapping method used to identify eco-friendly possibilities in the production process, are just a few of the methods that may be used to collect this essential input data. The use of artificial intelligence methods (such as fuzzy and agent systems) to transform qualitative and quantitative data into the new metric is being explored. Each level of the manufacturing system's green score will be reflected in the metric data. In Fig. 4, the International Definition (IDEF0) model is used to describe the assessment layer's inputs, processes, controls, and output.

5.1 : Green Manufacturing Planning

At this phase, a green plan for enhancement and execution is developed based on the results of the preceding evaluation. Limiting factors in the planning stage include ensuring a sufficient supply of goods to fulfil consumer demand. This is crucial for assuring industrialists that becoming green won't have a detrimental impact on their output as has been often imagined. There is a predetermined sequence that the evaluation score will mandate for the planned development to occur at the operational (machine) level, the process level, and the system level. The prepared plan shall include of both qualitative and numerical action items, including but not limited to those pertaining to the kind and consumption of materials and energy, process changes and improvements, and the introduction and development of technology.

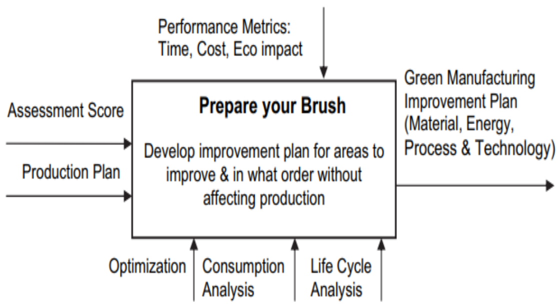

Fig No. 6 - Model IDEF0 for a green layer of planned enhancements and rollout.

Due to the goals and system restrictions at this point, the production of the plan is essentially an optimization process. The objective function will have conflicting goals, such as decreasing energy and material use while keeping costs low. Constraints on this ideal strategy will include meeting demand while maintaining quality and finishing on schedule. Methods like the Analytical Hierarchy Process (AHP), CSP methods, the Theory of Constraints, and meta-heuristics should be investigated for their potential to help develop this strategy. As noted, the strategy will be carried out by translating ideal energy and material levels into the need for a new architecture, new process parameters, and new control parameters. In Fig. 5, we see an IDEF0 model for the green layer of implementation and improvement planning.

5.2 – Green Manufacturing Implementation

After an ideal strategy has been formulated, it may be put into effect in stages. Material, energy, process, and technology are all broken down and executed independently or in tandem with one another. To achieve a smooth transition without interrupting production, a systematic approach should be devised for that implementation, one that strikes a balance between the existing system configuration and practises and those of the ideal plan.

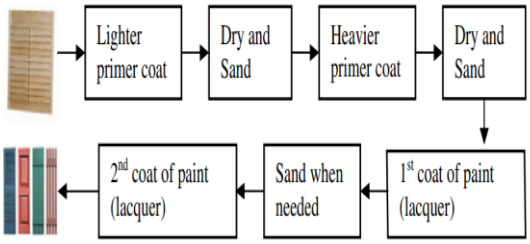

Fig No. 7 – Implementation Technique

The generated green manufacturing measure should be used in a reevaluation process after the execution of the green production strategy at each level. The degree of green progress at different production levels will be measured throughout the reevaluation process. The evaluation will determine whether the strategy was effective. Figure 6 depicts an IDEF0 model for the green manufacturing strategy implementation layer.

5.3 – Monitoring and Sustainability

Each manufacturing innovation is only as good as its capacity to endure in the long run. Every effort to implement green manufacturing must include considerations for the long-term future. One potential outcome at this juncture is the development of policies and guidelines for green manufacturing. In addition, green kaizen groups (or continual improvement groups and projects) should be a regular element of the planning and control processes in green universities, as should the monitoring of the greenness of production at each stage.

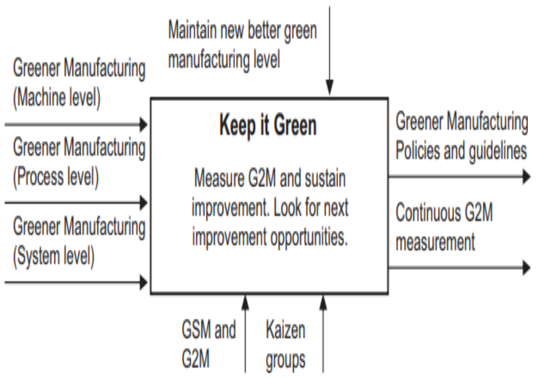

Fig No. 8 – Monitoring Process

At this point in the green transformation process, we're dealing with a standard dynamic control issue. The results of the ongoing evaluation of environmental friendliness are meant to inspire more green development initiatives, and so forth. Figure 7 depicts an IDEF0 model for a long-term green manufacturing implementation layer.

V. INDUSTRIAL CASE STUDY

An effective application of the suggested system model to a real-world case study is shown here. Many initiatives to increase the paint department's eco-friendliness at a wood product firm are outlined in this case study. The spray priming, sanding, and spray printing processes associated with a single product line (shutters) were the key areas of attention. At that point, they apply a light primer coat, wait for it to dry, sand it, add a stronger primer coat, wait for it to dry, sand it, apply a coat of paint (lacquer), sand where necessary, and apply a second and final coat of lacquer (shown in Fig. 8).

Wood product manufacturers successfully implemented green manufacturing operations utilising the suggested system model, as shown in Fig. 9. In the appendix, Table A1 details the yearly savings in money, time, resources, and pollution avoided thanks to the green manufacturing practises put into place. Figure 9 and Table A1 show that the suggested system model architecture's green manufacturing approach is both practical and effective.

VI. CONCLUSION

Under the scope of this article, a system model this model to achieving green manufacturing was provided. Green manufacturing processes may now be planned, designed, and managed in an open mixed architecture. Starting with assessing the manufacturing system's existing green level (what colour are you?), the architecture then details the steps required to create an ideal green plan, put that plan into action (paint it green), and ensure that the improvements are maintained over time (keep it green). The system approach acknowledged the multi-tiered nature of green transformation, which occurs primarily at the operational (machine), process, and system levels. The designed architecture also demonstrated how several performance metrics that are reflective of the green manufacturing system's overarching goals are used to regulate the operation of its various layers. International definition IDEF0 models were also used to illustrate the procedures, tools, and intended output of each layer.

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