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Sustainable Production: The New Manufacturing Paradigm

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INTRODUCTION

"Sustainability can't be a sort of a moral sacrifice, political dilemma, or a philanthropically cause; it must be a design challenge"

– Bjarke Ingels [1]

Many manufacturing organizations view sustainability as a legal constraint and hence define it as the conformance to environmental laws and regulations. The aim of this paper is to demonstrate that if a manufacturer focuses on sustainability, it can become a competitive advantage and lead to lower operating costs, higher quality, enhanced customer satisfaction, and increased revenue. The ultimate goals of the methods and tools presented in this paper will allow manufacturers to:

- Increase business competitiveness through reduced operating costs and reduced waste;
- Protect the environment by reducing pollution;
- Increase customer satisfaction through improved environmental protection;
- Accelerate the ability of an organization to adapt and thrive in a changing business environment; and
- Improve corporate images as the organizations excel beyond competitors.

The focus of this paper is to empower companies and organizations to utilize sustainability as a competitive advantage to deliver higher performance. Many organizations are able to increase profits for segments of their operations by reducing costs, raw material purchases, and other operating costs. However, many companies do not have the capability to perform comprehensive sustainability implementation due to time constraints and lack of knowledge in the field.

It can be easy for an organization to get wrapped up in the emotions of environmental protection and sustainability often associated with environmental activists or ‘tree huggers’. The real challenge is to have these initiatives make business sense for manufacturers. In other words, how will sustainability initiatives improve the profitability or operating budgets for manufacturers? That is the focus of this paper, to translate sustainability into terms that appeal to a CEO and that will motivate him or her to action based on the economic benefits as well as the environmental benefits. A 2013 survey conducted manufacturing companies in the USA that had implemented sustainability strategies indicated an average annual cost savings of $155,000 USD per company. These are facts and figures that motivate upper management and CEOs. The central concept is that a company can help the environment and their economics at the same time.

THE NEED FOR A PARADIGM SHIFT

The world and manufacturing have changed significantly over the past century. The world is now a complex global economy and many organizations are exploring a variety of international low cost option to create, produce, and transport manufacturing goods. This can create a very complicated environmental management issue for international manufacturing organizations, as what may be a legal waste disposal alternative in one country may be illegal in another area where the organization operates. To compound matters, societies are shifting to a convenience oriented mind-set, world populations are increasing, and subsequently waste generation is shifting, which is creating new environmental impacts.

One of the central purposes of sustainability is to reduce or eliminate the environmental impacts of individual companies and industries. An understanding of these impacts is critical when addressing environmental issues to provide direction for reduction efforts. Some of these impacts are more important than others, thus a comprehensive understanding will allow managers and engineers to focus on more serious problems. This section provides an overview of these impacts with a focus on the effects not the sources. These impacts are:

Space availability – as the world population increases and cities grow, the available space to dispose of solid waste decreases. By minimizing waste levels, disposal space will also decrease making land available for other uses.

Landfill leachate – leachate is liquid that is generated from a landfill that is created from decomposing waste, created after rainwater mixes with the chemical waste in a landfill, or liquids present in the landfill. Once it enters the environment, the leachate is at risk for mixing groundwater near the site which can have very negative effects. Groundwater is the source of drinking water for over 40% of the population, and up to 90% of the population in rural areas [2]. It was formerly assumed that this source of water was not subject to contamination, but recent studies have shown that this source of water can in fact become contaminated. Landfill leachate may be virtually harmless or dangerously toxic, depending upon the characteristics of the material in the landfill. Typically, landfill leachate has high concentrations of nitrogen, iron, organic carbon, manganese, chloride and phenols. Other chemicals including pesticides, solvents and heavy metals may also be present. Modern landfill sites require that the landfill leachate be collected and treated. Since there is no method to ensure that rainwater cannot enter the landfill site, landfill sites must now have an impermeable layer at the bottom. The landfill leachate that collects at the bottom must be monitored and treated if required. This liquid can be treated in a similar manner to sewage, and the treated water can then be safely released into the environment.

Global warming - One study reports that U.S. landfills are responsible for 3.8% of the global warming damage from human-sources in the U.S. Municipal solid waste landfills are the largest source of human-related methane emissions in the United States, accounting for about
25 percent of these emissions in 2004 [3]. This gas consists of about 50% methane (CH4), the primary component of natural gas, about 50% carbon dioxide (CO2), and a small amount of non-methane organic compounds. In 2003, U.S. landfills generated 131.2 teragrams methane in terms of carbon dioxide CO2 equivalents (where a teragram or one million metric tons). Reducing the amounts of solid waste disposed in landfills would reduce methane generation and subsequently reduce global warming.

Consumption of natural resources – a large component of solid waste minimization is recycling. Recycling reduces the consumption of virgin natural resources by utilizing perceived waste materials. For example, production of recycled paper uses 80% less water and 65% less energy, and produces 95% less air pollution than virgin paper production. If every American recycled their newspaper just one day a week, the U.S. would save approximately 36 million trees a year. For every four-foot stack of paper recycled, one tree is saved and deforestation is minimized. Recycling also reduced environmental impacts due to mining. For example, by recycling aluminum, the need for the raw mineral bauxite is eliminated, which in turn eliminates the need for mining and smelting.

Loss of habitat – although it is difficult to accurately quantify habitat loss, many animal species are displaced by the creation of landfills and the effects of deforestation. By minimizing waste levels and increasing recycling, available habitats for animals will not be disrupted by the development or expansion of landfills and the effects of deforestation to acquire virgin raw materials.

EVOLUTION OF MANUFACTURING PARADIGMS

Table 1 provides a timeline of manufacturing paradigms since the mid-1850's. As displayed in the table, manufacturing has evolved from a craft based enter enterprise, to flexible production, to mass customization and is now entering sustainable production

Table 1. Manufacturing Paradigms.

Paradigm	Craft Production	Mass Production	Flexible Production	Mass Customization and Personalization	Sustainable Production
Paradigm started	~1850	1913	~1980	2000	2020?
Society Needs	Customized products	Low cost products	Variety of Products	Customized Products	Clean Products
Market	Very small volume per product	Demand > Supply Steady demand	Supply > Demand Smaller volume per product	Globalization Fluctuating demand	Environment
Business Model	Pull *sell-design-make-assemble*	Push *design-make-assemble-sell*	Push-Pull *design-make-sell-assemble*	Pull *design-sell-make-assemble*	Pull *Design for environment-sell-make-assemble*
Technology Enabler	Electricity	Interchangeable parts	Computers	Information Technology	Nano/Bio/Material Technology
Process Enabler	Machine Tools	Moving Assembly Line & DML	FMS Robots	RMS	Increasing Manufacturing

PROACTIVE SUSTAINABLE MANUFACTURING ROAD-MAP

Sustainability in a manufacturing environment can be a delicate balance between environmental protection, cost, and efficiency, but when an organization proactively considers sustainability while developing manufacturing processes, all three objectives can be met. The priorities for the industrial implementation of sustainability relate to the Triple Bottom Line (TBL) and include:

1. Environmental protection
2. Economic viability
3. Social and workforce integration

The 'sustainability roadmap' for manufacturing organizations has its roots in environmental protection. In terms of general priorities, this included closely monitoring, controlling, and reducing hazardous chemical usage, solid waste generation, air and water emissions, raw materials usage/scrap, environmental certifications, supplier relationships, transportation and logistical impacts, disposal of end of life, and regulatory compliance.

In terms of economic viability the priorities focus on cost related to sustainability initiatives and costs of regulatory compliance. Often times this involves detailed cost comparisons between current practices and more environmentally sustainable practices.

In terms of social and workforce integration the focus tends to be on the workforce and customer preference. A key question related to any new business practice or policy involves the acceptance by the workforce and customer base. If the workforce supports an initiative, it will significantly enhance its long term success and integrate the new practice into the 'culture' of the organization. Additionally, many customers are now investigating the environmental practices of organizations that they purchase goods; the customer base is growing that strongly considers an organization's environmental record and practices before making a purchase decision. This is both at a corporate and individual level.

The approach presented in this paper is based on the systems approach. The systems approach is a problem solving philosophy that focuses on a holistic view of an organization by analyzing the linkages and interactions between the elements that comprise the entire system. A system can be defined as group of interacting, interrelated, or interdependent elements forming a complex whole coordinated to achieve a stated purpose or goal. The systems approach emphasizes that the best method to understand problem is to understand the individual parts in relation to the whole. From a macro view, a system is comprised of inputs, processes, and outputs all revolving around accomplishing a given goal or goals. The definition and clear understanding of this goal is critical to defining the system in terms of its processes, required inputs and desired outputs. For example, there will be very different systems for an organization that produces solar cells versus an organization that provides food services. The key benefit of the systems approach to sustainability is that it addresses the problem from a business standpoint, consistently focusing on the organization's goals, and confronting the problem at every stage of the supply chain. Traditional approaches tend to only address the issue of sustainability at the end of the process, when determining how to
cost effectively remove or mitigate the waste from the facility. Many organizations also manage pollution and energy usage as compartmentalized 'problems' that are managed separately from its core processes. The central issue with this traditional approach is that by focusing on these individual outcomes, overall system optimization cannot be achieved. The systems approach addresses issues at all phases of the supply chain from raw material procurement to the design environmentally friendly processes that reduce emissions and pollution. Figure 1 provides an overview and roadmap of the system as it relates to business processes and sustainability.

Sustainability Metrics, Indicators, And Indices For Manufacturing Industries

Accurately measuring sustainability performance and tracking trends is a critical step for a successful program in any manufacturing organization. Measurement is needed before a company can begin to manage and improve the solid waste problem. Without knowing a starting point, or baseline measurement, it is very difficult to develop plan to meet organizational sustainability goals. This provides an overview of the various metrics to evaluate and track sustainability performance. The metrics can be refined into three categories:

- Environmental impact
- Business and financial performance

The Systems Approach to Sustainability

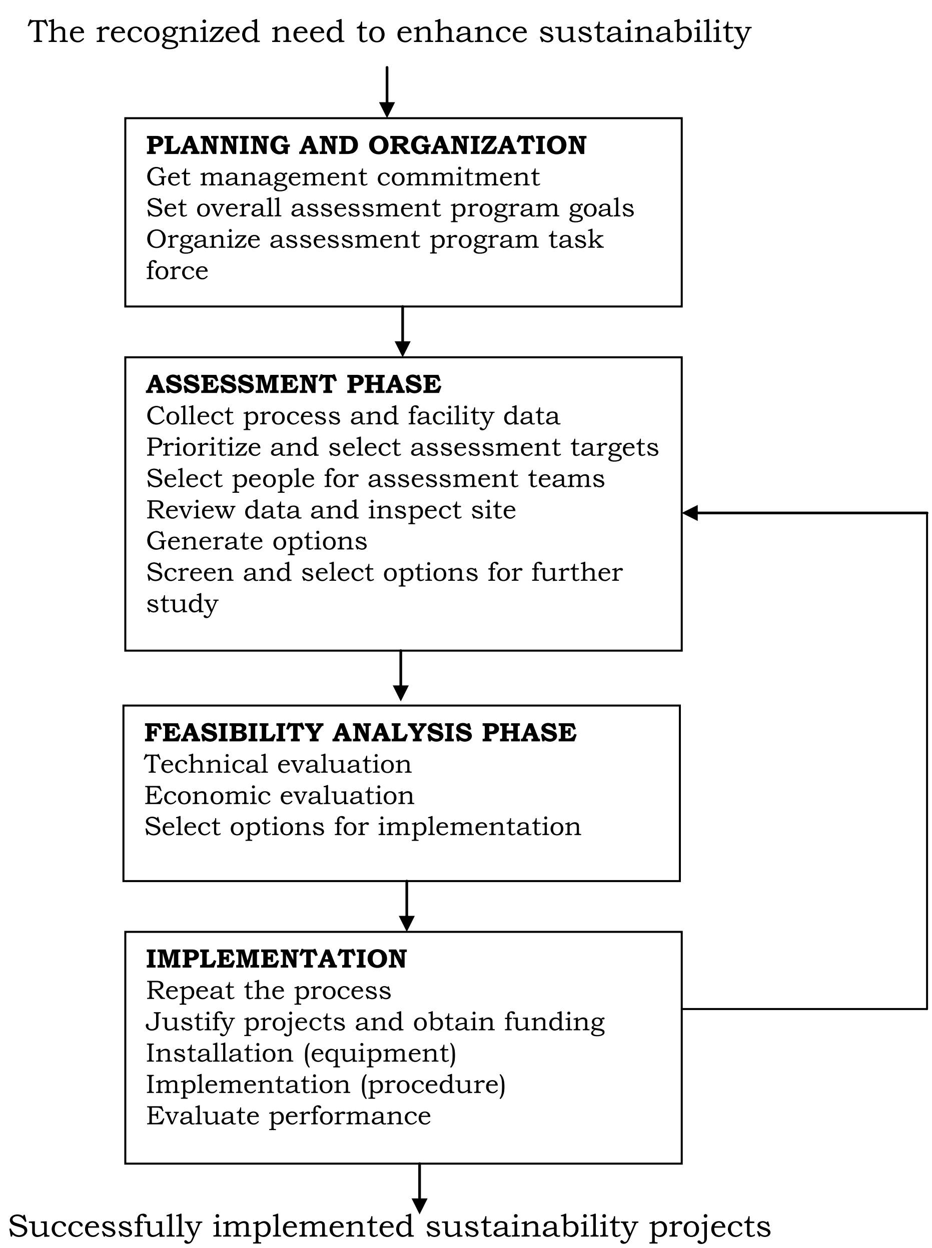

Figure 1. The Systems Approach to Sustainability.

Sustainability Indices

Measuring and tracking the sustainability performance of manufacturing companies is critical to its successfully management and reduction. For any process improvement, an accurate baseline must be created and monitored to measure success toward meeting a goal. Traditionally, sustainability efforts are reported by total output. For example, the plant generated 150 tons of solid waste this month, of this amount, 15 tons, or 10% were recycled. This measurement approach has a very serious short coming. The primary flaw is that is does not consider production levels or resource inputs. For example, if two similar manufacturing plants generated the same amounts of waste, but the second plant has only half the production volume, the second plant is not doing as a good job of managing its waste streams. Several other approaches have been developed to compensate for these flaws and allow for an equal 'apples-to-apples' comparison. Five of the most common metrics by which sustainability can be measured are:

1. Absolute measures
2. Measures indexed to a production based output
3. Measures indexed to a production based input
4. Measures indexed to throughput
5. Measures indexed to a production activity

Absolute measures are not normalized based on activity; they are the actual amounts recorded as in the 150 tons generated in a given month presented earlier. Measures indexed to production based output provide a ratio of waste based on production volumes for a given period of time. To calculate a production based metric, one would divide the waste by final output for a given period; for example with the 150 tons generated in a given month, if an auto company produced 125,000 vehicles their solid waste metric would be 150 tons/125,000 vehicles or 0.0012 tons/vehicle. This production output based metric allows for a more accurate comparison during periods of fluctuating activity when demand may rise and fall.

Measures indexed to a production based input, measures indexed to throughput, and measures indexed to a production activity are calculated in a similar manner expect they are normalized based on input (raw materials used as in steel production per month), throughput (gallons per month as in petroleum processing), and activity (number of customer orders per month) respectively. The choice of index should be selected based on the most appropriate and easily recordable activity for the given organization. Indexed metrics are very useful and allow for 'apples-to-apples' comparisons when activity levels change.

Sustainability Metrics

Common sustainability metrics relate to the TBL in terms of environmental protection, financial performance, and social wellbeing. From an environmental protection standpoint, this includes:

- Solid waste generation
- Recycling percentages
- Percentage of waste to landfills
- Hazardous waste generation
- Hazardous chemical usage
- Scrap generation
- GHG emissions
- Air emissions
- Waste water generation
- Energy usage
- End of life disposal methods and amounts

These environmental metrics are tracked using the most appropriate index-based measurement that fits best for the manufacturing organization. From a financial performance point of view, rates of return, payback period, sales, market share, and revenue are typically tracked. From a business standpoint, individual sustainability projects are evaluated based on their impact to the bottom line of the organization. An understanding of the financial benefits of sustainability projects is critical to in determining, evaluation, comparing, and selecting projects. In addition, a thorough understanding of the financial impact of the project will aid in promoting the project to upper management and other stakeholders. From a financial standpoint, the three areas that sustainability projects are evaluated are:

- Initial investment
- Payback period (and discounted payback period)
- Internal rate of return

The initial investment is the start-up funds required to begin a given sustainability program. This includes the cost for recycling bins, recycling provider fees, recycling equipment costs (balers, grinders, or electric hand dryers), and training costs. The payback period is the period of time (usually given in years), required for the project's profit or other benefits to equal the project's initial investment.

The internal rate of return (IRR) is the interest rate at which the present worth and equivalent annual worth of a project are equal to zero. Another way to think about the IRR is the annualized interest rate that a project earns over its life. In most cases, organizations have a predetermined minimum attractive rate of return (MARR), which is the minimum interest rate that the organization could accept as the return on a project and still remain profitable. For a given project, if the IRR is greater than or equal to the MARR, it is a profitable decision to accept the project.

Sustainability projects should be evaluated based on these three areas, the initial investment, the payback period, and the internal rate of return. The initial investment is important to determine and allocate the start-up funds an organization has available to begin the project. This is needed to determine starting point for the sustainability efforts. The payback period and the internal rate of return measure the 'success' of the project in financial terms.

From a social and employee wellbeing standpoint several tools exist to measure performance. Typically surveys are used to gauge employee and customer satisfaction. Mail-based or internet-based surveys are typically used as a low cost option. At a higher cost, panels may be formed to 'interview' groups of employees or customers to gauge their opinions towards the company. The results can be tracked over time to measure performance in this area.

CONCLUSIONS

Sustainability and environmental protection have emerged as core business requirements for manufacturing companies from a market share, legal, and customer expectation point of view. Legal systems and environmental regulations are strengthening and requiring manufacturing companies to place a stronger focus on minimizing environmental footprints. To assist in the process, many models, strategies, and tactics have emerged for manufacturing companies. Manufacturers need to place emphasis all components of their environmental footprints, including air, water, and solid waste. These aspects not only will better protect the environment, but also generate positive economic value as discussed regarding recycling commodity markets, energy reduction, and alternative energy implementation. From a business standpoint, traditional activities such as inventory control and transportation optimization offer both environmental protection in terms of fuel/emission reductions and significant cost reductions.

The need for sustainable operations will only increase and intensify in the future. World population is still growing at about 80 million people a year, or about 220,000 people per day if current trends persist, there will 2.5 billion more people on the planet by mid-century, bringing the total to about 9.2 billion [4]. Providing clean water, ample food, and other resources for this expanding population from resources on a finite planet pose a major challenge. Through sustainable operations and conservation, these concerns can be addressed.

As we progress into the future of manufacturing processes and systems, these issues will intensify and a focus on sustainability will increase. Below is a list of expected future trends in these areas:

- More legal regulation for developed and developing countries related to emissions, hazardous waste, and solid waste generation
- The integration of global sustainability initiatives for international corporations; companies will apply equivalent environmental policies in all countries of operation based on the most stringent regulations
- High competition from globalization and the need to drive down costs
- High consumer focus on sustainable companies
- Higher visibility of errors due social media and the rapid dissemination of information

Sustainability and environmental protection are now expectations to do business for manufacturers, no longer an option.

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