OVERVIEW OF THE PROPOSED SUSTAINABLE MANUFACTURING MEASUREMENT INFRASTRUCTURE

Asst. Prof. J. Porwal
Department of Mechanical Engineering,
IIT, Kharagpur,
India

ABSTRACT

As the pollution in environment, depletion of global resources and change in climate are exacerbating due to developing globalized industrialization, the industry of manufacturing is under constraint to match with the issues and handle competitiveness. Sustainable manufacturing has been suggested to attain the challenges faced by industrialized nations. In manufacturing the sustainability measurement is an enabler to evaluate performance quantitatively in sustainability in particular processes of manufacturing. A measurement infrastructure of sustainable manufacturing is suggested in this study. The tools involve metrics repository and sustainable indicators, guidelines, measurement processes and sustainability performance report and analysis. The measurement infrastructure of sustainability offers a basis for decision making components growth and is expected to be combined tightly into development processes of business strategy.

Keywords: Performance analysis, Sustainability manufacturing and measurement, Infrastructure, Sustainable performance analysis

Introduction:

The industries of manufacturing are challenged with a new leading confrontation on sustainability due to natural and energy resources being devastate, deplete and deterioration of global environment and human beings following greater quality of life. In this situation there is a difficult requirement that the processes of manufacturing in development of products must be sustainable. While it is a leading tool of civilized manufacturing itself is the major source of using natural resources with toxic wastes and by-products always harmful to surroundings. In this study the worldwide community of research has to enhance new metrics and methods to sustainable manufacturing [1]. UN (United Nations) already refers that sustainable development is to attain current requirements without compromising the capability of future generations to attain their requirements [2]. On another side in
development sustainability is the ability of organization to progress its economic state without settling the social equity and natural surroundings that offers the life quality for all residents of community in current or future. Therefore sustainability is a rivalry problem in entire sectors of manufacturing. According to US Department of Commerce definition sustainable manufacturing is the making of a manufactured product with methods that have reduced negative influence on surroundings conserving natural resources and energy are secure for communities and employees and are sound economically [3]. The manufactured products design must have considerations on complete product life cycle involving the economic advantages of manufacturers and the complete product influence on society and surroundings.

OECD (Organization for Economic Corporation and Development) one of the major firms on enhancing sustainable manufacturing asserted numerous forward looking tasks [4]. One of the activities is to develop sustainable indicators, analysis software tool sets and performance metrics to support benchmark performance of business. Additionally ASMC (American Small Manufacturers Coalition) recognizes an analytic threat to United States manufacturing that the measurement systems of sustainability are deployed insufficiently (ASMC news, June 11, 2009). An infrastructure of measurement is required critically to enhance sustainable manufacturing. This study explains a development effort on infrastructure of measurement for sustainable manufacturing. The second section presents a study on present status on metrics development and sustainable indicators. The third section offers an overview of infrastructure for estimating the performance of sustainability in processes of manufacturing. The fourth section explains an instance to evaluate performance using an indicator. The fifth section overview the present development work and future scenarios.

**Background:**

The organizations sustainability is always examined by 3 dimensional perspective
surroundings, economy and society [5]. This multi-dimensional sustainability is always critical to accomplish because these views are interlinked in a composite way [5]. There are numerous within firm or international trials to analyze and measure the performance of these 3 dimensional sustainability by developing qualitative or quantitative indicators of sustainability. These indicators are utilized to estimate every dimensional performance and can be reviewed in reports of sustainability for stakeholders.

One of the renowned international indicator sets of sustainability performance is developed by GRI (Global Reporting Initiative). The Global Reporting Initiative indicators are classified as addition and core. They are classified in these 3 dimensions namely society, economy and environment. Global Reporting Initiative is a voluntary initiative intended to offer a component for making decisions in numerous levels such as operation, management and external or internal stakeholders [7]. The Global Reporting Initiative provides a standard way of sustainability performance report so that manufacturers can evaluate their processes performance. Another global framework for evaluation of sustainability performance is the process of eco-efficiency assessment developed by WBCSD (World Business Council for Sustainable Development) in 2000 [8]. This structure offers general indicators and activity specific indicators for entire activities. It suggests how to carry out the complete process of eco-efficiency assessment and the growth of an eco-efficient report. Varied from the above two structures which offers particular group of indicators an ISO 14301 offers suggestions to firms on how to grow their own indicators for performance of environment [9]. The development framework of indicator can be outlined by numerous methodologies: a) lists of issue or category; 2) a matrix of goal oriented indicator, and 3) model of pressure source response [13]. Additionally sustainable indicator confirming checklist such as checklist of community indicator [10] may be helpful in property purposed specification of indicator. Usualy the leading problem of these indicator structures
is that the concentration is on stakeholders external reporting rather than on internal data required to optimization or re-design for actual eco-innovation and requirement for decision making. In this study manufacturers required a standardized structure for environment of sustainable manufacturing in which they could track and evaluate their performance of sustainability easily.

Management and evaluation of sustainability performance:

This part explains a suggested measurement infrastructure for sustainability performance. Presently major tools in the suggested structure involve methodologies of sustainability measurement, sustainable indicator repository and report of performance.

Sustainable indicator repository:

Sustainable indicator repository comprise of essential multi-dimensional indicators specific to sector indicating the manufacturing systems sustainability and performance benchmarking metrics of preferred indicators within eco-creative strategies of business. Developed or adapted indicators normally have certain features like [10, 11]:

**Relevant:**

The indicator must reveal useful meaning on processes of manufacturing under estimation. It must fit the measuring performance purpose.

**Measurable:**

The indicator must be capable of being estimated qualitative or quantitatively in multi-dimensional outlook.

**Accessible data:**

The indicator must be based on accessible data. The information required to be accessible or can be collected when it is essential.

**Understandable:**

Indicator must be simple to be perceived by community particularly for those who are not professionals.
Usable/Reliable:

The data offered by indicator must be useful and trusted. Reliable calculation is important.

Flexible:

An indicator must be compatible with expressions of open standard such as ML documents and ontology base documents to assist big term flexibility and archival for future generations.

The metrics of sustainability is a group of calculations corresponding to standard indicators that are utilize to estimate the performance of sustainability of a firm. Based on measured outcomes companies can evaluate their indicators of sustainability, examine the sustainability trend and carry out accounting of sustainability. Time dependent evaluations of indicators allow managers and engineers to know specific metrics trends and the gap to aim at given time and allow them utilize the data in the process of internal decision making for eco-innovation. Efficient indicators permit designers and engineers to concentrate on particular interest areas during the process of design. Depending on metrics can be confusing if these metrics do not seize the rivalry system drivers. Mainly the influence and quality of engineering design are related closely to the metrics design utilized in the analysis [12]; therefore how to organize and refer the indicators and metrics decides the effectiveness of them in repository of sustainability indicator.

Process of sustainability measurement:

The process of sustainability measurement is referred as an operations sequence with essential tools and instruments and having the objective of deciding the indicator value. The major need has to be for external accountability reporting and internal decision making therefore the process of sustainability measurement must comprise the data of instrument and measurement process, target values, related indicators and objects according to strategies of business. Fiksel et al [14] in 1999 highlighted 4 principles of sustainability measurement which can support organizations to mention the challenges related with reporting and
calculating sustainability: 1) triple bottom line, 2) consideration of product lifecycle; 3) value and resource; and 4) lagging and leading indicators. They mentioned that the process of sustainability performance measurement generally includes 3 phases namely plan structure, review and implement. One of the major needs of sustainability measurement is that each indicator is offered by measurement methods, reference materials, procedures and instrument certification based on standard in a tightly integrated way with operations of business throughout the lifecycle of product. In this study the author established numerous guidelines for measuring process. The first step is that the sequence of measurement operation must be traceable and logical so that it can be comparable and repeatable in time dependent lifecycle of product. The second step is that the instruments of measurement must be calibrated and certified in standard way for robustness. The third step is that the magnitude and sources of measurement mistakes is expressed explicitly. The fourth step is that the measurement uncertainty expression required assuring to open standards.

**Report and Analysis of sustainability performance:**

Based on the estimated outcomes engineers not only report but also make essential decisions for their operations of business such as redesign. The evaluation of performance must be performed in numerous phases with sufficient tools of analysis. In this case existing practices like design or ERP for six sigma [15] can be better components for reporting and analysis of internal performance. On the other side certain indicators like carbon dioxide emission or enterprise based gases of green house for indicators of external communication. In this case global reporting initiative can be a better component for external communications. Sustainability reporting and communication and business strategy must be associated with management and evaluation of sustainability performance. To make this appear sustainability communication and information must be handled in similar way
as strategic accounting and planning [16]. Consequently, entire selected and developed indicators and metrics have essential relations with standard measurement instruments and methodologies throughout the lifecycle of a product. Designers or engineers can track the performance of sustainability with indicators through standard-based methods of repeatable measurement. Furthermore, they can access evaluated metrics through different design analysis components and utilize the outcomes in their processes of decision making for eco-innovation of products.

**Case study: Emission of carbon dioxide**

The author suggested an easy machine subassembly. This subassembly comprises of 3 tools namely X, Y and Z. The author assumes that the tools X and Y are directly machined by an organization and Z tool is offered by a supplier. The operations of machining are applied to X and Y within company’s organization.

Preferred metrics and indicators:

The author utilized the method of calculation of these metrics and indicators in [17]. First, the used machining energy in an individual machining operation is evaluated by the following equation:

$$E = \int (F(t) - F(t)) + (v(t) - v(t)) dt$$

(1)

Secondly, the CW (carbon weight) can be converted by energy used by the below mentioned equation.

$$CW = f(E)$$

(2)

**Process of energy measurement:**

Energy used indicator is related directly by the metric of energy. The indicator can be evaluated by machining parameters like speed of surface, cutting force, cutting time, rate of material removal, etc. Usually, these parameters can be supervised in monitoring system of real-time machine evaluated by dedicated instruments and collected from log of machining system, etc. For instance, the supervision system can account entire parameters of machining in XML format through network. A precision machining
center has a better velocity control so that little velocity variants can be avoided. Besides the author approximate the time of process by evaluating the volume of removal for every process and regard that parameters dependent on time, speed of surface, cutting force and removal rate of material to be steady. Hence the approximated equation is indicated as:

\[ E = k(F \cdot vt) = k \cdot F \cdot v \cdot \left( \frac{V_r}{R_a} \right) \]  

(3)

**Aggregation of metric throughout an organization:**

All energy consumed in making a product or component can be evaluated by storing the outcomes in each individual operations of machining. To aggregate the consumption of assembly level energy from the outcomes of component level, engineers estimate metrics or indicators at any organization level from operation to enterprise.

**Summary and Future Work:**

In this study the author has suggested an initial growth of an infrastructure for management and measurement of sustainability performance. This involves measurement process, indicator repository and evaluation of performance on bottom line. All selected or developed indicators, methods of measurement, values of benchmark and algorithms of computing will be accessible to public. The process of measurement and the reproducibility and repeatability with the alternative and required measurement tools and instruments must be traceable to corresponding standards of measurement. The process of sustainability performance evaluation is combined tightly with strategy of business for eco-innovation of enterprise throughout the lifecycle of product. The future work involves building a testbed surroundings for the suggested infrastructure of measurement and the guidelines of implementation for the combined framework for management and evaluation of sustainability performance for sustainable manufacturing eco-innovatively.

**References:**


Evanston, Illinois.


