Performance Measurement System for Green Manufacturing

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ABSTRACT
Performance measurement system (PMS) plays an important role in the successful implementation of advanced manufacturing systems like green manufacturing. However little attention has been paid to design and implement performance measurement systems (PMSs) for green manufacturing. The paper highlights the imperatives of performance measurement systems (PMSs) for green manufacturing and review some of the most widely used PMSs. A PMS based on the traditional hierarchical system is presented for green manufacturing.

Keywords: Green Manufacturing; Performance Measurement Systems.

1. INTRODUCTION
Manufacturing companies are under increasingly diverse and mounting pressures due to more sophisticated markets, changing customer choice and global competition. The market for products is becoming increasingly international. Thus, in order to compete in global markets, manufacturers necessarily need to acquire excellent performance. To know the excellent performance, measurement is important. Therefore, Performance measurement is a prerequisite to any improvement efforts in enterprises in order to sustain the improved performance and if possible, improve it further (Sahay, 2000). An enterprise’s measurement system strongly affects the behavior of people, both inside and outside. If organizations are to survive and prosper in information age competition, they must use measurement systems derived from their strategies and capabilities (Maskell, 1992).

Melnyk and Smith (1996) defined green manufacturing as “a system that integrates product and process design issues with issues of manufacturing planning and control in such a manner as to identify, quantify, assess, and manage the flow of environmental waste with the goal of reducing and ultimately minimizing environmental impact while also trying to maximize resource efficiency”. As enterprises introduce green manufacturing they need new method of performance measurement to control and improve their plants. Traditional performance measurement systems are invalid for the measurement of green manufacturing practices, as they do not supply the business with the required information to compete in their industry. As traditional performance management systems are based on management accounting, they primarily concerned with cost (Oakland, 1993). But in today’s manufacturing environment, cost-based measures are no longer the only basis for decision-making. Enterprises now require performance measurement systems that are based on strategic, tactical and operational parameters.

2. BACKGROUND
In recent years, performance measures have become paramount important as they are the prerequisite for continuous improvement of any organization. They are mainly used to
compare the performance of different organizations, plants, departments, teams and individuals, and to assess employees (Kenerley and Neely, 2003). For companies to ensure achievement of their goals and objectives performance measures are used to evaluate, control and improved production processes. Many organizations have spent considerable time and resources implementing balanced performance measurement systems (Kaplan and Norton, 1996). The literature in the field of performance measurement emphasizes the importance of maintaining relevant measures that continue to reflect the issues of importance to the business. The performance measurement literature has had two main phases. The first phase began in the late 1880s and went through the 1980s. In this phase the emphasis was on financial measures such as profit, return on investment, return on sales and productivity. The second phase started in the late 1980s as a result of changes in the world market. Companies began to lose market share to overseas competitors who were able to provide higher quality products with lower costs, more variety and environment friendly. To regain a competitive edge companies not only shifted their strategic priorities from low cost production to quality, flexibility, short lead time and dependable delivery, but also implemented new technologies and philosophies of production management such as computer integrated manufacturing (CIM), flexible manufacturing systems (FMS), just in time (JIT), optimized production technology (OPT) and total quality management (TQM), Green Manufacturing (GM). The implementation of these changes revealed that traditional performance measures have many limitations and the development of new performance measurement systems is required for success (Kenerley and Neely, 2003; De Toni and Tonicha, 2001; Ghalayini and Noble, 1996; Stalk, 1988; Wee and Quazi, 2005). To overcome these difficulties researchers developed many non-traditional performance measures like quality, time, speed, flexibility, customer services etc. This list, along with many similar ones proposed by a number of distinguished authors, as key enablers for competitive advantage. The problem is – times change and with them sources for a competitive edge. Only a few researchers have come with theories of competitiveness that have mentioned environmental friendliness as a source competitive advantage. The main reason for this is the lack of performance measures for green manufacturing (Sangwan, 2006).

However, environmental awareness is probably the singular topic in which general public interest is growing most rapidly, not only in developed nation but developing nations also as the ill effects of global warming and ozone layer depletion are affecting all the nations as (Andersen and Fagerhaug, 1999):

- The number of environmental preservation societies/associations are increasing dramatically
- The amount of legislation related to environmental protection has exploded during the last few years, both at national and at international level.
- Unnatural climatic effects suspected to stem from pollution have increased and received much media attention, e.g., global warming, El Niño, etc.

It is a fact that one cannot manage what one cannot measure. Thus, performance measurement is a key element in enabling performance management, performance improvement, performance documentation, etc. When combining the pivotal importance of environmental friendliness with the need for performance measurement, it is evident that “green manufacturing performance measurement” is crucial for the overall success of the enterprises in today’s competitive business environment. However, at present, managers have difficulty in
assessing the impact of green manufacturing because of the lack of appropriate performance measurement system. Without a proper performance measurement system, it is difficult to justify green manufacturing as an alternative option.

3. REVIEW OF PERFORMANCE MEASUREMENT SYSTEMS
This section presents a limited chronological history of performance measurement systems.

3.1 Sink and Tuttle Framework
One of the first approaches to performance measurement was published by Sink and Tuttle (Sink, 1985, Sink and Tuttle, 1989). The model claims that the performance of an organizational system is a complex interrelationship between the following seven criteria:

1. Effectiveness, doing the right things, at the right time, with the right quality, etc. Defining the criterion as a ratio, effectiveness can be defined as Actual Output/Expected Output.
2. Efficiency, this is an input and transformation process question, defined as Resources Expected to Be Consumed/Resources Actually Consumed.
3. Quality, where quality is an extremely wide concept. To make things more tangible, quality could be measured at six checkpoints: Upstream systems, inputs, the transformation value-adding process, outputs, downstream systems, and the quality management process.
4. Productivity, this is the traditional ratio of Output/Input, but it appears as just one of several criteria.
5. Quality of work life, one essential, but often forgotten element contributing to a well performing system.
6. Innovation, a key element in sustaining and improving performance.
7. Profitability or budget ability, the ultimate goal for any organization.

Sink and Tuttle (1989) urge companies to focus on the following four areas:

- Performance Improvement Planning.
- Performance Measurement and Evaluation.
- Performance Improvement and Control.
- Cultural Support Systems.

A major objection to Sink and Tuttle’s model is the almost total lack of environmental focus. None of the seven criteria are focused on the environment and neither is the underlying system.

3.2 TOPP System
One example of a more recent performance measurement system is the TOPP system, which was developed by SINTEF (SINTEF, 1992) in Norway in partnership with the Norwegian Institute of Technology (NTH), the Norwegian Federation of Engineering Industries (TBL), and 56 participating enterprises. In TOPP, four methodologies were used:

- Self-audit (questionnaire).
- Extended audit (experts)
- Self-assessment (continuos improvement, trends).
- Benchmarking (breakthrough).
The TOPP views performance along three dimensions (Effectiveness, Efficiency and Changeability) as illustrated in Fig. 1.

![Fig. 1: Performance Model from TOPP](image)

A main concern in TOPP is the many surrounding factors that influence the productivity and competitiveness of a company. This is illustrated in the stakeholder model (see Fig. 1.). In the stakeholder model the environment is one of several factors influencing the company. Our experience is, however, that the environment is becoming one of the most important stakeholders in any company.

The environmental focus of the TOPP system is better than in Sink and Tuttle’s model. In the questions for the self-audit and the extended audit, the environment is a major part. The environmental focus is not, however, truly integrated with the other aspects and areas as a holistic environmental measurement system should be.

### 3.3 Balanced Scorecard

One of the most well known conceptual performance measurement frameworks is the balanced scorecard developed and promoted by Kaplan and Norton (1992). The balanced scorecard proposes that a company should use a balanced set of measures that allows top managers to take a quick but comprehensive view of the business from four important perspectives, see Fig. 2. In turn, these perspectives provide answers to four fundamental questions:

1. How do we look to our shareholders (financial perspective)?
2. What must we excel at (internal business perspective)?
3. How do our customers see us (the customer perspective)?
4. How can we continue to improve and create value (innovation and learning perspective)?

Evidently, the balanced scorecard includes financial performance measures giving the results of actions already taken. It also complements the financial performance measures with more
operational non-financial performance measures, which are considered as drivers of future financial performance. Kaplan and Norton (1992) argue that giving information from four perspectives, the balanced scorecard minimizes information overload by limiting the number of measures used. It also forces managers to focus on the handful of measures that are most critical. Further, to use several perspectives also guard against suboptimisation by compelling senior managers to consider all measures and evaluate whether improvement in one area may have been achieved at the expense of another.

![Fig. 2. The Balanced Scorecard](image)

According to Ghalayini et al., (1997), the main weakness of this approach is that it is primarily designed to provide senior managers with an overall view of performance. Thus, it is not intended for or applicable at the factory operations level. Further, they argued that the balanced scorecard is constructed as a monitoring and controlling tool rather than an improvement tools. Bourne et al (2000) argued that although the balanced scorecard is a valuable framework suggesting important areas in which performance measures might be useful, it provides little guidance on how the appropriate measures can be identified, introduced and ultimately used to manage business. They also concluded that the balanced scorecard does not at all consider competitors.

There are other common drawbacks, which can be drawn from the literature (Ahmed, 2002), such as:

- The balanced scorecard framework is more complex than it looks and some companies in haste select inappropriate sets of measures and think they have built their measurement system on this basis.
- The “learning perspective” is still weak, with people factors being treated only superficially, in particular the corporate learning (i.e. knowledge management), which is entirely absent from the framework.
- A number of leading measures such as environmental, health and safety, customer satisfaction are not clearly focused.
4. PERFORMANCE MEASUREMENT SYSTEM FOR GREEN MANUFACTURING

To develop an approach to green manufacturing performance measurement, a model must be outlined that can separate the different levels at which performance measurement can be undertaken and also illustrate the areas that should be covered by green manufacturing performance indicators. In general, performance measurement can occur at the traditional three levels:

- The strategic level, performance measures that can tell an organization about the soundness of their strategic decisions. While these strategic decisions and directions they advocate impact the extent to which the organization operates in an environmentally friendly way, there generally tends to be fewer performance indicators at this level.
- The tactical level, which can be said to encompass issues like which suppliers are used, which overall manufacturing technologies are utilized, etc. As the performance measures at the strategic level, these are important in setting boundaries for the actual operations of the organization.
- The operational level, measurement of the performance of the operations and business processes of the organization. This is by far the level in need of the highest number of performance measures and which in practice determines the environmental impact of the company.

A framework for the performance measurement system for green manufacturing based on the traditional hierarchal levels is shown in Fig. 3. The researchers should find the performance measures at these three different levels for green manufacturing as outlined in sub-sections.

4.1 Performance Measures at Strategic Level

As previously mentioned, indicators at this level are usually few and for the purpose of direction setting. A few relevant indicators of this nature are:

- The existence of an environmental policy. Notice that by environment, we do not only think of nature and wildlife, the environment also includes quality of life in local communities. True environmental concern.
- This means not only an on-the-surface avoidance of potentially environmentally hazardous operations, but rather a state of mind where every day is made a struggle to minimize any negative impact on nature stemming from the company’s activities.
- Contributions to improvement of the environment. It is one thing to do everything a company can to avoid further damage to nature. A truly convincing environmental attitude is seen in organizations that go even further and try to find ways of repairing or improving damage.
- Presence in areas that are threatened by pollution, eradication of wildlife or vegetation, or deterioration of quality in areas of life.
4.2 Performance Measures at Tactical Level
The indicators that we have suggested at this level focused mainly on the environmental performance of the actors in the supply chain of which the enterprise is a part. The core areas that should be covered are:

- Strategic choices made by the enterprise’s suppliers, along the same lines as the indicators defined for the strategic level of the organization itself.
- Levels of waste, pollution, the use of energy, and the use of irreplaceable resources by the enterprise’s supplier.
- Contents of harmful substances of the input goods purchased from the suppliers.
- Levels of waste, pollution, the use of energy, and the use of irreplaceable resources in the enterprise’s own transformation processes. This topic is, however, the core focus of the performance indicators at the operational level.
- Contents of harmful substances of the output products delivered by the enterprise to the marketplace, either to the next tier of manufacturers or end customers.

4.3 Performance Measures at Operational Level
As previously mentioned, the number of performance measures will normally be highest at the operational level. At the same time, this is the level where the need to tailor the indicators to the specific situation is largest. Thus, instead of trying to define general measures for every single business process, we have defined some key dimensions that should be kept in mind when developing specific indicators, and also given some examples of such indicators.

The main dimensions of performance at this level are:

- Amounts of waste produced by or in connection with the business process.
- Amount of polluting discharges to air, sea, and land generated by the business process.
- Amount of energy consumed by the business process.
- Amount of irreplaceable natural resources consumed by the business process.

5. CONCLUSIONS
An enterprise’s ability to undertake its operations in a way that does not damage the environment is a vital part of the enterprise’s competitiveness. To be able to improve its
environmental friendliness, an enterprise will require a performance measurement system that also covers this dimension. To aid enterprises in implementing such a system, we have outlined which levels and dimensions should be covered and also given some specific examples of performance measures for green manufacturing performance measurement. It is our hope that the enterprises of this world realize the importance of environmental friendly operations, both for the sake of the planet and for their own competitiveness, and start measuring their green performance.

REFERENCES
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