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Energy and utility management maturity model for sustainable manufacturing process

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ABSTRACT

The manufacturing industry, one of the top consumers of natural resources, produces extensive carbon emissions that create the need for a sustainable manufacturing process, a topic of significant research interest. In the recent decades, the advancement of environmental technology and introduction of comprehensive environmental management systems have highlighted the intangible benefits of environmental management practices and their potential to drive organizational competitiveness. Accumulating evidence on the potential benefits of environmental protectionism has given rise to a series of environmental management practices and systems, such as energy informatics, environmental management standardization frameworks, and green supplier management and collaboration. However, existing literature lacks a clear conceptualization and a coherent theoretical framework of environmental management. In addition, no systematic framework exists for the design and implementation of environmental management practices that guide organizations in deciding on the practices or systems that they should implement given their organizational situations. Thus, this study aims to develop an energy and utility maturity framework for systematic measurement and management of natural resource consumption. Specifically, the proposed framework, energy and utility management maturity model (EUMMM), was designed based on the capability maturity model integration (CMMI). EUMMM has two major functions. First, it provides an assessment framework for analyzing the maturity level of energy and utility management in organizations. Second, it provides a progressive framework to guide organizational advancement in energy and utility management. A collaborative pilot study was conducted to validate the effectiveness, practicability, and convenience of the EUMMM. The results indicated that EUMMM successfully led the participating companies to move along the environmental management maturity path. Theoretically, this study extends the application of CMMI to the context of natural resource management and develops a progressive framework for energy and utility management maturation. Practically, this study provides a robust guideline for practitioners in analyzing and advancing energy and utility maturity levels to achieve a sustainable manufacturing process.

1. Introduction

Environmental performance and firm performance are two competing ends in the manufacturing process. Researchers used to believe that environmental practices used up organizational resources and distracted organizations from strengthening their competitiveness (Gadenne et al., 2008; Montabon et al., 2007; Pil and Rothenberg, 2003; Sarkis and Cordeiro, 2001; Wagner et al., 2002). However, with the advancement of environmental technology and introduction of comprehensive environmental management systems in the recent decades, researchers have begun to realize the intangible benefits of environmental management practices and their potential in driving organizational competitiveness. With proactive environmental management practices, companies generate additional business opportunities, promote production efficiency and effectiveness, and reduce the cost of manufacturing and pollution management (Christmann, 2000; Caniato et al., 2012; Hui et al., 2001; King and Lenox, 2002; Montabon et al., 2007; Pil and Rothenberg, 2003; Wagner et al., 2002; Yang et al., 2010; Zhu et al., 2005).

Accumulating evidence on the potential benefits of environmental protectionism has given rise to a series of environmental management practices and green innovations, such as energy informatics (Chen et al., 2008; Watson et al., 2010), frameworks on environmental management standardization (Corbett and Kirsch, 2001;

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Matouq, 2000; Matuszak-Flejszman, 2009; Vastag et al., 1996), and green supplier management and collaboration practices (Matuszak-Flejszman, 2009). However, existing literature lacks a clear conceptualization and a coherent theoretical framework of environmental management (Lucas, 2010). No systematic framework exists for the design and implementation of environmental management practices that guide organizations, particularly those that lack resources and expert knowledge, in deciding the environmental management practices or systems that should be implemented given their specific organizational situations. In several situations, environmental management practices are applied in an ad hoc manner. In addition, organizations seeking higher levels of environmental performance find no systematic framework for assessing the maturity levels of their existing environmental management systems and determining ways to improve progressively the manufacturing process toward environmental sustainability. A mismatch between the maturity level of environmental management and the plan of environmental management improvement may lead to the non-fulfillment of organizational targets, and consequently a low return on investment. Such a mismatch or non-readiness may also lead to a situation wherein the potential benefits of environmental management cannot be fully realized in actual business situations.

Given the increasing concerns over environmental performance for sustainable development, the expanding set of environmental management practices, and the limitations of existing benchmark environmental management frameworks, this study aims to develop a simple and easily implementable energy and utility maturity framework called energy and utility management maturity model (EUMMM) in the manufacturing sector. The framework has two major functions. First, EUMMM provides an assessment framework (with five maturity levels) for analyzing the maturity level of energy and utility resource management in organizations. Second, it provides a progressive framework (with four phases of maturation processes) to guide organizational advancement toward maturity in energy and utility resource management.

This framework has been designed based on capability maturity model integration (CMMI). The proliferation of programs to improve competitiveness through continuous improvement in productivity, product quality, waste reduction, and energy efficiency has gained popularity in the past few decades. These programs require certain common capabilities; thus, consolidating these programs under one umbrella of process improvement is advantageous. CMMI, which is widely applied in process-improvement programs for quality and productivity, provides a framework of process improvement for such initiative. Thus, we have adopted the CMMI for the conceptualization of the EUMMM, in which, assessment activities provide useful feedback for continuous improvement. Our proposed framework is advantageous over existing environmental management frameworks for the following reasons. (1) It is more practical and easier to implement than existing environmental management frameworks. Existing environmental management frameworks, such as EN16001 and ISO50001, have been developed primarily for large or listed companies. These frameworks are far too complicated for organizations that lack professional and financial resources for implementation. (2) It adopts the concept of continuous improvement that enables organizations to advance their maturity of energy and utility management progressively. (3) It contains both the assessment and maturation guideline for improving energy and utility management.

This study has both academic and practical contributions. Theoretically, this study extends the application of CMMI to the management of natural resources in organizations. Furthermore, this study develops a progressive framework to explain the process of energy and utility resource management advancement from one maturity stage to another, thereby helping researchers understand how sustainable development may be achieved in organizations. Practically, the current study provides a robust guideline for practitioners in analyzing and advancing the maturity of energy and utility resource management. This paper is organized as follows. First, a review on existing environmental management frameworks is provided. Second, the CMMI model is explained as a reference framework for the development of EUMMM. Third, EUMMM is presented as a composite of assessment and progressive frameworks, and the application of the model using a collaborative practice research study is described. Finally, the conclusions and contributions of the study are provided.

2. Literature review

In this section, we first provide a general understanding on energy efficiency management standards to gain a brief picture on existing benchmarking frameworks, and then briefly review the academic work published on energy management research.

Different international energy management standards guide enterprises in improving energy utilization performance and efficiency. First, one well-known program is the Energy Star (Environmental Protection Agency (EPA), 2003), a joint program between the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy. Through home and business guidelines, Energy Star protects the environment by promoting energy-efficient products and practices. EPA provides a proven strategy for superior energy management with tools and resources, as well as guidelines that assist organizations in improving their energy performance step by step.

Second, EN 16001 (Sustainable Energy Ireland, 2009) is the energy management system of the European standard published in 2009. It complies with ISO 14001 and is based on the plan-do-check-act cycle. EN 16001 helps organizations set up a comprehensive energy management system and continually improve their energy utilization performance, leading to lower energy costs and less greenhouse gas emissions.

Third, the United Nations Industrial Development Organization (UNIDO) and the International Organization for Standardization (ISO) developed an energy management system standard in 2008 for the integration of energy efficiency into the management practices of industrial enterprises (United Nationals Industrial Development Organization (UNIDO), 2008). The standard, ISO 50001, establishes the benchmarking energy management framework for industrial plants, commercial facilities, and entire organizations. Based on the framework, enterprises can develop energy efficiency goals, plan for interventions, prioritize energy efficiency measures and investments, monitor and document energy management performance and results, and ensure continuity and constant improvement in energy efficiency.

Fourth, module 4 of the Energy and Greenhouse Management Toolkit, developed by the State Government of Victoria (State Government of Victoria, 2002), provides details on the development of energy management systems. The module presents the following sequence of events for energy management: organize management resources, appoint an energy manager and create an implementation team, prepare a corporate energy management policy indicating energy reduction targets, establish an energy use monitoring and reporting system, identify energy saving opportunities through energy audit, prepare a detailed action plan based on the audit findings and budgets, implement staff awareness and training programs, implement projects, and report and review results and conduct an annual review. Other national standards for energy management systems used in Europe include DS2403 in Denmark, SS627750 in Sweden, IS 393 in Ireland, UNE-216301:2007 in Spain, and VDI 4602/1 in Germany.