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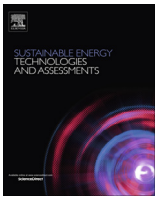

Original article

Sustainability index development for manufacturing industry

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ABSTRACT

Manufacturing industries are adopting new techniques and philosophies to address the acute shortage of non-renewable energy. Many of these manufacturing industries are focusing on achieving sustainability in every possible stage of their production, from raw material to the recycling of waste. Thus, the significance of using renewable energy, properly handling waste, and progressively conserving the environment is increasing day by day. In this research, the definition of sustainability is quite specific: being productive while making little to no impact on non-replenishable resources. The objective of the research is to determine the sustainability index of manufacturing plants. Since the topic has a broad scope, this research is limited to small and medium scale industries, which have common sets of operation and defined process plans. Besides, the focus is on non-hazardous waste and the indicators of the index are selected with respect to energy efficiency, workers' health and safety and waste reduction potential. An interactive model has been developed to determine the sustainability index based on user responses. Based on the sustainable index, the model is able to provide suggestions to improve sustainability as well as carbon footprint reduction. The research has used datasets from various projects of the Industrial Assessment Center (IAC) at West Virginia University to build the knowledge database. The interactive model is validated by case studies from the IAC. The outcome of this research is a model that can assist industry to identify their shortcomings in achieving sustainability, determine the carbon footprint reduction potential, and compare the sustainability index as a benchmark measure.

Introduction

Sustainability in manufacturing has recently received an increasing amount of attention. It is considered as an effective solution to advance the continuous growth and expansion of the manufacturing industry [1]. Recently National Council for Advanced Manufacturing (NACFAM) has shaped a policy initiative towards sustainable manufacturing [2]. The covered sectors of manufacturing lie within North American Industry Classification System (NAICS) 311-339 definition [3]. The manufacturing industry sectors have significant anomalies. Minimal effort has been given on sorting the anomalies; however, sustainable manufacturing is considered a key step in moving forward. To provide a useful tool for comparing sustainability across processes and companies, a comparative and quantitative scoring system or index is essential. The literature lacks clear efforts for creating a sustainable manufacturing index. The goal of creating such an index is to enhance the decision-making capability for modifications to manufacturing processes. Current efforts have failed to provide a rigorous index for examining the sustainability of manufacturing processes. To provide a useful tool for comparing sustainability across processes and companies, a comparative and quantitative scoring system is critical.

The aim of this research is to develop an interactive model to develop the sustainability index for small and medium scale manufacturing industry. According to Industrial Assessment Center (IAC) program of Department of Energy (DOE), the manufacturing industries with gross annual sales below 100 USD million and employees fewer than 500 at plant site are considered as small to mid-sized category [4]. A low score in sustainability index will indicate the area that needs improvement. Simultaneously, the carbon foot print will be determined to enhance the energy and waste management efficiency potential. This research addresses the problems of overcoming the research gap in sustainability determination by integrating the various indicators. The contribution of this research is threefold: 1) introducing an index based scoring system 2) evaluating the benefits of having sustainable policy 3) identifying the potential scope of opportunities within

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existing manufacturing industry. The flow of information of this paper has been presented in the following manner: Section 1 of this paper has discussed the need of sustainable manufacturing indices and Section 2 has covered the literature review in this area. Section 3 has explained the methodology of determining the sustainability index (SI). Section 4 has modeled the determination of the sustainability index and Section 5 has conducted analysis. Section 6 of this paper has provided the conclusion.

Literature review

Until now, agricultural systems, ecological systems, and financial institutions have introduced sustainability indices despite having many different approaches applied in various ways without any standardization. Most of the research has been focused on few factors with a holistic approach, although pragmatic, quantitative analysis is much needed in this area. First, this paper has investigated the different sectors where sustainability index has been exercised. Dow Jones Sustainability Indices (DJSI) in collaboration with RobecoSAM provided a financial sustainability index for investors [5]. Although the authors are working with a varying definition of sustainability, the method for determining sustainability provides a baseline for calculating diversified indices. Lee and Huang use fifty-one sustainability indicators to determine a sustainability index for Taipei, a city of Taiwan [6]. The authors have divided the indicators into four different categories such as economic, social, environmental, and institutional dimensions. Zhou et al. discuss how to work with composite indicators while condensing multidimensional indices into one index score [7]. Composite indicators depend on aggregation methods of sub-indices, normalization methods, and a specific weighting scheme. The conceptual requirements for a City Sustainability Index (CSI) were discussed by Mori and Christodoulou [8]. They place importance on creating a CSI and compared the sustainability performances of various cities to observe the global impact of cities on the environment and human life compared to their economic contribution. Chavez and Alipaz created a dynamic and aggregated watershed sustainability index indicator [9]. They integrated hydrologic, environmental, life and policy issues to develop their model. A sustainability index should have a proper definition with specific objectives. For example, according to Emerson et al., Environmental Performance Index (EPI) focuses on the impacts of countries on the environment, which includes twenty-five indices with two objectives: (i) reducing environmental stresses to human health and (ii) protecting ecosystems and natural resources [10]. Singh et al. combined all the initiatives and framework for sustainable indicators. The selection of indicators is very important [11]. Mayer mentioned the impacts of selecting a wrong set of indicators in his review article [12]. He put significant importance on indicator selection and accumulated the current discrepancies in sustainability indices. Sands and Podmore worked on design and development of an Environmental Sustainability Index (ESI) and described a case study used to validate the performance of the index [13]. The EPIC model (Erosion Productivity Impact Calculator) was used and fifteen sustainability sub-indices were chosen to determine the index. Ngai et al. exposed the intangible benefits of environmental management practices and their potential to drive organizational competitiveness [14].

A collective review on sustainable manufacturing efforts by previous researchers are depicted as below. Nagalingam et al. measured the performance of product returns with recovery for sustainable manufacturing [15]. They developed a framework for performance measurement with the help of six sigma methodology. A survey of sustainability indices for countries was developed by Bohringer and Jochem [1]. The article examined the power of indices on policy making. Smith and Ball described the steps required to achieve sustainable manufacturing though modeling material, energy and waste flows [16]. Despeisse et al. showed that some companies such as Brandix, Ford, Sony, and Rolls-Royce are already reaping the benefits of focusing on sustainable manufacturing [17]. According to Ball et al., zero carbon manufacturing (ZCM) can be considered as a constituent element of sustainable manufacturing. ZCM improves the environmental performance of systems by understanding and examining MEW process mapping [18]. Some of the latest techniques on sustainable manufacturing has been implemented by Fuzzy based assessment models. Singh et al. has done a study on fuzzy interference system models for the evaluation of manufacturing sustainability of small and medium enterprises [19]. At first a list of sustainability indicators for manufacturing small and medium sized enterprises (SMEs) is identified and weak areas are detected to enhance the performance of overall sustainability. This approach will assist the decision maker to select an appropriate strategy to reduce the environmental impact.

There are many key performance indicators required to define the sustainability index of a manufacturing plant. Some researchers specify that a lean approach can be one of these indicators, even though the notion is not fully supported by all the peers in researching sustainability index in manufacturing plants. Marhani et al. discussed how lean approaches can help the cause of achieving sustainability [20]. Abolhassani et al. analyzed how lean approaches can impact a continuous improvement process in a manufacturing industry [21]. Yang et al. showed that lean practice will not improve environment performance all the time [22]. This is even though reducing waste and reusing resources across the spectrum of a manufacturing system is mandatory within the context of lean manufacturing. Gunasekaran and Spalanzani investigated the sustainability of manufacturing and services [23]. The researchers classified and performed a critical review to develop a framework for sustainability business development, and suggested future research directions with tools, techniques and some performance measures and metrics for sustainable business development. The classification scheme for the literature in manufacturing sustainability are i) sources of sustainable challenges and problems, ii) advances in sustainable business development in manufacturing and services, iii) sustainability in product/process design and development, iv) sustainability in supply operations, v) sustainability in production operations, vi) sustainability in distribution chain operations, and vii) sustainability through remanufacturing, recycling and reverse logistics.

Despeisse et al. discussed sustainable manufacturing approaches and cross functional factory modeling. They focused on the gap in knowledge on how to acquire expected conceptual aims at the operational level [24]. method to provide connection between the generic sustainability concepts and more specific examples of operational practices for resource efficiency in factories were presented in the paper. Finally, a resource flow analysis was tested and presented via a prototype tool. The overall analysis focuses on the events within the ecosystem of a factory (gate to gate). It accounted for location and time as well as manufacturing processes in a manner that was not supported by the independent disciplines of either process simulation or building energy analysis tools. Sustainable Energy Ireland published a draft of an energy management system which complies with ISO 14001 and is based on the plan of to-do-check-act cycle [25]. Sustainable energy Ireland (SEI) is referring to it as EN 16001 and it helps organizations set up a comprehensive energy management system and continually improve their utilization performance, leading to lower carbon footprint and lower energy costs. ISO 50001 works in the same direction by establishing the benchmarking energy management framework for industrial plants, commercial facilities and organizations.

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