Fuzzy AHP based Plant Sustainability Evaluation Method

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Abstract

Plant Sustainability has gained much prominence in the field of manufacturing in the recent past which has led to develop generic methodologies for plant sustainability evaluation. Wide focus has been given to environmental and economic aspects than the social domain in majority of them. It is rare to find that, the generic methodologies are capable of detail analysis especially when taken into account quantitative and qualitative factors which is commonly available among social domain. This paper presents a generic model to evaluate manufacturing plant sustainability using Fuzzy Analytic Hieratical Process (AHP). Since, social aspects frequently lead to qualitative evaluations of the experts, fuzzy logic has been used to convert the qualitative judgments into evaluable numbers, allowing Fuzzy AHP to perform an all-inclusive analysis. Moreover, the paper proposes a tool that can perform analysis at variable resolutions of available plant data. This variable resolution tool will allow evaluation to be carried out on feasibility studies on existing plants.

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Keywords: Manufacturing Plant sustainability, AHP, Fuzzy logic, Triple bottom line, Social impacts, life cycle assessment

1. Introduction

With the rapid industrial development taken place within last century has led to many environmental and social implications around the world. The scale of these implications has gradually increased over the last couple of decades and presently, many developing and developed nations are in vulnerable states with different scales. In order to find a
solution to unsustainable rapid development and its inherent implications, in 1987 a committee was appointed under the leadership of Brundtland (a politician from Norway later became director general of WHO). The committee came up with a concept of Sustainable Development, which proposed to decouple economic development with excessive consumption of natural resources. The main concept behind sustainable development philosophy is to look at development through triple bottom line (TBL) where Environmental and social aspects were considered equally along with Economical aspects in the development even though previously it focused only on economic benefits.

When development is the main concern, manufacturing sector globally plays a significant role, in the means of which industry that fulfils societal materialistic needs. Thus, it has been exponentially increased over the years and has created considerable environmental and social impacts. A holistic view spanning on product, processes and entire supply chain is requires to achieve sustainability in manufacturing (Jayal et.al [1]). Subsequently many tools and methods have been developed in last three decades which tend to drive towards sustainable development concepts in product, process and supply chain perspective. At the product level design concept has moved beyond the traditional 3R (Reduce, Reuse, Recycle) concept to 6R concept (Reduce, Reuse, Recovery, Redesign, Remanufacture, Recycle) [1]. At the process level, planning and technical development has been focused on minimizing resource consumption, GHG emissions and wastages. For further illustration, supply chain can be classified by the phases of Product life cycle as pre-manufacturing, manufacturing, use and post-use stages. However for many products, manufacturing is considered to be the critical stage among all, as it comprises enormous number of resources such as machinery, human involvements, value addition, etc. Therefore, evaluating manufacturing plant’s sustainability is a paramount requirements to promote Sustainable practices. Essentially, the tool that will be used to evaluate the sustainability of a plant should look into TBL with equal importance.

There are wide spectrum of tools and methodologies available in the literature over past couple of years. These include sustainability evaluation tools based on Product [1,2,3,4,5], Process or Plant [1,2,6,7,8,9,10,11,12,13,14] besides life cycle or based on supply chain [15]. Initial studies are focused on proposing evaluating indicators. The Global Reporting Initiative (GRI) [17,18] has published a framework based on TBL in 1999 to assess the sustainability of a company [7]. In 2011 this has further elaborated to a set of 81 indicators which are expressed in various measuring units which need high amount of collected data. Importantly, these indicators can be used to evaluate any type of industry. However, this framework does not contain a way to aggregate the results of the assessment which limits the possibility of cross comparison. UN commission on sustainable development has published about 140 indicators at 2001 [7] to evaluate the governmental progress on sustainable development. These indicators have developed based on TBL and has included another bottom line as an institutional aspects. In 2002, Institute of Chemical Engineers (IChemE) [7,19] also introduced a model equally addressing TBL which consists of 50 indicators relevant to process industry. One of the common gap highlighted from these frameworks is the limited space for the cross comparison among the various industries due to the absence of an aggregating method to assess results. But these indicators can be used as a guideline to develop a tool to assess the plant sustainability.

In addition, many tools have been developed in recent years [6,7]. Major problem identified in those tools and methods is the complexity of the evaluation method due to the variety of indicators having different types of measuring units with different level of importance. T. Lu et.al [2] presents a metrics to evaluate the sustainability of a manufacturing process. Though it is not presented as an analytical method to generate an aggregated value to enable the cross comparison within different type of industries, it has suggested to use Analytic hierarchy Process(AHP) to determine the relative importance of different influencing factors and discuss the possibility to use Fuzzy logic to get measurements of non-deterministic elements. However some studies have been limited only to deterministic elements to avoid any complexities in assessment process [9,10,14]. But most of the recent studies have moved on further as using Fuzzy inference method [11,12] and Fuzzy TOPSIS [15] to analyse both deterministic and non-deterministic elements in a common bed. Especially Singh et.al [11] has developed a generic plant sustainability evaluation model based on 3BL and fuzzy inference system to assess the sustainability of manufacturing SMEs. They have focused on development of common indicators for sustainability assessment from SMEs. Abdul et.al [12] suggests similar type of approach to evaluate product and process sustainability. Other than those Danfang et.al [8] developed an application which consists with three types of questions which answered by a rating scale or a binary scale or a percentage scale. This also has the capability to assess qualitative and quantitative factors. Even this article discuss about getting an
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