Sustainability Assessment of Environmentally Conscious Manufacturing Companies

S. Ozmehmet Tasan, B. Felekoglu and E. Ozmehmet

Abstract Sustainable manufacturing is becoming increasingly important with substantial social, environmental and economic benefits, thus companies show more tendency to adopt this concept. Recognizing the benefits of sustainability, manufacturing companies need to measure how sustainable they perform. However, sustainability can be thought as an abstract issue which is difficult to measure and also assess. Measuring sustainability is a continuously evolving research area which generates various sustainability indicators to assess companies' production activities. Practically, while evaluating the sustainability performance of a manufacturing system, various indicators should be considered simultaneously. This study focuses on the usage of sustainability indicators to assess the sustainability of a production company from a multi-criteria decision making point of view. As a case study, the sustainability performances of an international beverage company which produces non-alcoholic drinks were evaluated. TOPSIS method was adopted as an assessment method with the use of several conflicting indicators simultaneously.

Keywords Sustainability indicators · Sustainable manufacturing · Multi-criteria decision analysis

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1 Introduction

The interest to manufacturing in a sustainable way has increased in industry as the companies started to realize the substantial social, environmental and economic benefits of producing their products in a more sustainable way. From manufacturing perspective, *sustainability* can be defined as diminishing the negative effects of manufacturing operations on the triple constraints of sustainability i.e. people, planet and profit, simultaneously. Manufacturing actions considering the environmental issues contribute to the firms for gaining competitive advantage in the market. Because the actions concern the environment includes typically the product and process focus which are useful to derive value improvement and cost decline (Wiktorsson et al. 2008). Additionally, the firms considering the social issues such as health and welfare of their workers and stakeholders gain similar strategic advantages.

Sustainability indicators are developed with the same sense of financial indicators and utilized to measure the success of the company in terms of sustainability and sustainable manufacturing (Veleva and Ellenbecker 2001). Despite the vagueness of the sustainability concept, indicators serve to monitor and assess social, environmental and economic impacts of manufacturing activities (Warhust 2002).

This study proposes the usage of Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to assess manufacturing sustainability by using several conflicting indicators simultaneously. The structure of the study is as follows: section two provides better understanding regarding the terms sustainability and sustainability indicators. Section three covers TOPSIS method as a sustainability assessment methodology. Section four presents the case study in an international beverage company which produces non-alcoholic drinks. Finally, the findings are discussed and concluded in section five.

2 Sustainable Manufacturing

The concept of *sustainability* and *sustainable development* was first mentioned in the report of World Commission on Environment and Development (WCED) (United Nations 1983, 1987). The report indicates that additional efforts for increasing the environmental investments will provide sustainable development. Since the fundamental objective is to sustain human life and keep planet in a way that every generation can live, sustainable development is the main concern in the concept of sustainability. WCED, known as the Brundtland Commission of United Nations, defined sustainability and sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (United Nations 1987). WCED also depicted

that sustainable development is not a definite concept that promise achieving a fixed state; it is the process that rely on environmental, social and economic aspects.

Sustainable development concept has been stimulating interest in many research and application areas. Among these areas, the focus of this study is manufacturing. With sustainable manufacturing, companies aim to increase their operational efficiency, reduce their waste while respecting environment and align their operations with social, environmental and economic regulations. By this way, companies can achieve potential benefits of sustainable manufacturing such as increasing competitive advantage, reaching new customers, building public trust, strengthening their reputation, improving health and welfare of their stakeholders.

Recognizing the benefits of sustainability, manufacturing companies need to assess how sustainable they operate using performance measures which are called sustainability indicators.

When the literature on sustainable manufacturing reviewed, it can be seen that most of the research focused on developing sustainability indicators (OECD, n.d.; Rennings and Wiggering 1997; Krajnc and Glavic 2003; Raizer-Neto et al. 2006; Joung et al. 2013). Among these studies OECD (n.d.) gives a list of sustainability indicators some of which are related to manufacturing and can be used for evaluating the sustainability of manufacturing operations. Rennings and Wiggering (1997) investigated the linkage between environmental and economic aspects of sustainability indicators which shows promising potential for assessing sustainable manufacturing. Krajnc and Glavic (2003) categorized production indicators into three, namely social, environmental and economic. Environmental indicators were classified as input and output, whereas economic indicators were classified as financial and employee related. Besides, indicators to measure sustainability in industrial manufacturing were grouped under product, operation and management areas in Raizer-Neto et al.'s (2006) study. One of the most comprehensive categorizations of sustainable manufacturing indicators were given in Joung et al.'s (2013) study. They identified five dimensions of sustainability in assessing company's manufacturing operations. These dimensions are formed from environmental, economic, social, technological and performance points of view.

In the light of this literature review, it can be stated that various sustainability indicators related to manufacturing operations exist. In this study, we will be using a combination of various sustainability indicators and consider them simultaneously while evaluating the sustainability performance of manufacturing operations.

3 Sustainability Assessment Methodology: TOPSIS

There are numbers of tools and techniques for assessing sustainability. A comprehensive review of these methods can be found in Ness et al. (2007) study. They categorized these methods into indicators and indices, product related assessment and integrated assessment.

In this study, manufacturing related sustainability indicators, which conflicts with each other, are used. Due to the conflicting nature of these indicators, assessment using simple calculation methods becomes useless and inefficient. To overcome this issue, an integrated assessment method, i.e. TOPSIS method, has been used as a multi-criteria decision analysis method. In multi-criteria decision making problems, the purpose is not optimizing the solution. In these problems, criteria are evaluated simultaneously in order to find the compromise solution. The criteria and its outcome must be measurable and valid for every alternative decision.

TOPSIS was developed by Hwang and Yoon (1981). The idea behind the method is that the chosen alternative is expected to have the shortest Euclidean distance from the ideal solution and contrarily have the farthest distance from the negative ideal solution. The ideal solution is hypothetical solution that corresponds to maximum attribute of all attribute values in database where comprising the satisfying solution. In this sense, the negative ideal solution is hypothetical solution as a consequence that all attribute values correspond to minimum attribute values in database (Rao 2007). Thereby TOPSIS gives the closest solution to the hypothetically best and also which is farthest from the hypothetically worst.

TOPSIS can be summarized in six steps. In the first step, the evaluation matrix is constructed using listing alternatives horizontally and criteria vertically. In the second step, the center values in the evaluation matrix are non-dimensionalized by dividing each center value by the norm of the total outcome vector. In the third step, relative importance is calculated by multiplying the matrix values by normalized weights of each criterion. In the fourth step, positive and negative ideal solutions, which are the set of best or maximum/worst or minimum values of each criterion respectively in the evaluation matrix, are found. In the fifth step, the Euclidean distances are calculated using the separation of each matrix value from the ideal solutions. In the last step, overall or composite performance score of each alternative is calculated in terms of relative closeness to the ideal solution.

4 Case Study

In the case study, we gathered the sustainability related data from an international beverage company which produces non-alcoholic drinks. The company has operations in Turkey, Pakistan, Kazakhstan, Azerbaijan, Kyrgyzstan, Turkmenistan, Jordan, Iraq, Syria and Tajikistan, and it is headquartered in Turkey. Data considered in this case study used for assessing the sustainability of factories in Turkey, Kazakhstan, Jordan and Azerbaijan are shown in Table 1.

It is not possible to conduct a study for Azerbaijan since data regarding its manufacturing activities are not available on reports. However, information provided for the years of 2011 enables TOPSIS method to compare those countries in terms of indicators represented in Table 2. The year of 2011 is chosen in order to

Table 1 Data gathered for 2011 provided by factory reports from four countries

	Turkey	Jordan	Kazakhstan	Azerbaijan
Water use ratio (L/L)	1.42	2	1.7	1.74
Water use amount (m^3)	3,850,537	137,847	510,591	306,059
Energy use ratio (MJ/L)	0.255	0.455	0.333	0,222
Total energy use from primary resources (mil.mj)	301.21	12.55	59.55	11.59
Solid waste ratio (g/L)	3.38	11.19	2.69	1.16
Recycling ratio (%)	94.95	88.9	85.34	92.47
CO_2 emission ratio (g/L)	30.1	56.03	49.46	49.44
Total shipping emissions (g/L)	15.57	21.46	7.17	13.53
Combustible use ratio for shipping (L/KL)	5.67	6.81	2.61	5.21
Sales volume (million unit box)	546.8	12.9	70.5	42.3
Total working hour	9,405,144	915,899	1,231,340	929,920
Total number of employees	2820	368	599	269

Table 2 Sustainability indicators and their meanings

Sustainability indicator		Definition
$I_{1,1}$	Water use ratio (L/L)	Water used per produced amount of liter
$I_{1,3}$	Specific water consumption (million m^3/million unit box)	Water use amount/sales volume
$I_{1,5}$	Energy use ratio (MJ/L)	Energy used per produced amount of liter
$I_{1,5}$	Specific energy consumption (million MJ/million unit box)	Energy use amount/sales volume
$I_{1,7}$	Solid waste ratio (g/L)	Solid waste per liter produced
$I_{1,9}$	Recycling ratio (%)	Absolute value
$I_{1,10}$	CO_2 emission ratio (g/L)	CO_2 emission per liter produced
$I_{1,11}$	Total shipping emission ratio (g/L)	Absolute value
$I_{1,12}$	Combustible use ratio for shipping (L/KL)	Combustible used/produced amount of liter
$I_{5,1}$	Sales volume per working hour for an employee (million unit box/h)	Total working hour per employee/Sales volume

apply TOPSIS method because the data is provided completely for those countries where the consistent analysis is possible considering the designated indicators. In addition to existing product indicators, a new indicator is included in the analysis. Differently from the previous analyses, new indicator appertains to the group of social indicators. These indicators are specified as *I*.

The sustainability indicators are calculated and the evaluation matrix is formed as shown in Table 3. Indicators indicating the values of absolutes mass are assigned relatively small weights since the records related to those value can change the

Table 3 Evaluation matrix

	$I_{1,1}$	$I_{1,3}$	$I_{1,4}$	$I_{1,5}$	$I_{1,7}$	$I_{1,9}$	$I_{1,10}$	$I_{1,11}$	$I_{1,12}$	$I_{5,1}$
Turkey	1.42	0.00704	0.255	0.55086	3.38	94.95	30.1	15.57	5.67	0.16395
Jordan	2	0.01069	0.455	0.97287	11.19	88.9	56.03	21.46	6.81	0.00518
Kazakhstan	1.7	0.00724	0.333	0.84468	2.69	85.34	49.46	7.17	2.61	0.0343
Azerbaijan	1.74	0.00724	0.222	0.274	1.16	92.47	49.44	13.53	5.21	0.01224

Table 4 Performance values of countries

Countries	$C_{i,j}$
Turkey: $C_{5,1}$	0.42806
Jordan: $C_{5,2}$	0.46546
Kazakhstan: $C_{5,3}$	0.68918
Azerbaijan: $C_{5,4}$	0.80482

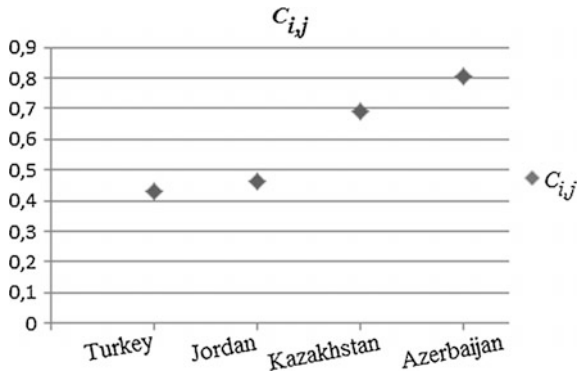

Fig. 1 Performance values for Turkey, Jordan, Kazakhstan and Azerbaijan at 2011

capacity of the plant. As a result of the TOPSIS method, performance values obtained are shown in Table 4.

It is clearly seen from Fig. 1 that Azerbaijan had better performance at 2011 amongst other countries. Turkey and Jordan share almost the same scores despite the differences of data.

While Turkey and Jordan performs nearly the similar results, Kazakhstan is positioned almost in the middle of the point between Jordan and Azerbaijan where Azerbaijan stands as a best performed country.

Detailed examination of the evaluation matrix can clarify this situation. Azerbaijan and Jordan have similar records according to production activities. Nevertheless, Jordan has higher values where the data is expected to be at the lower levels. Figure 2 illustrates the radar graph which provides better understanding for this statement.

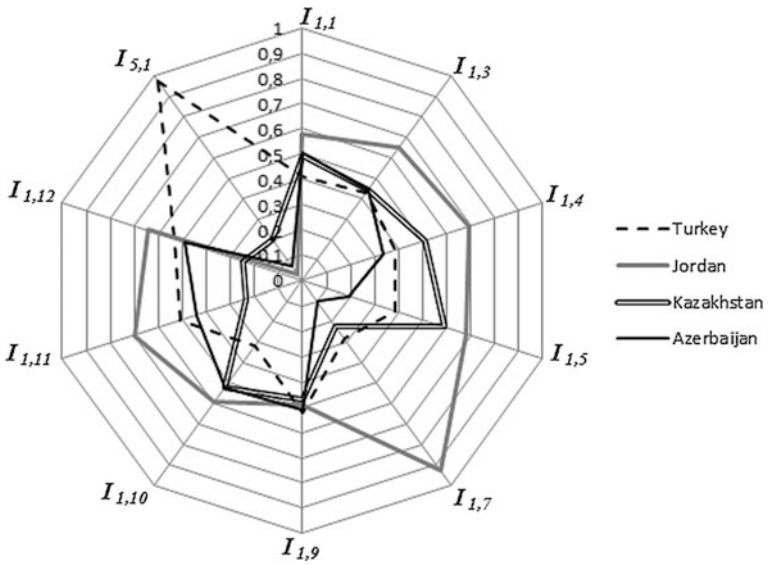

Fig. 2 Radar graph representation of evaluation matrix

5 Conclusion

As the world has become global, environmental problems due to manufacturing activities have become global problems too. The concept of using resources without utmost consuming them and manufacturing without harming the environment as much as possible led the term sustainability and sustainable development to emerge. Beside economic pressure and consumption of resources, manufacturers have been facing increasing costs and need for creating added value for customers. As a result of these circumstances, manufacturers started to adopt the concept of sustainability and recently, the interest of sustainable manufacturing has increased more than ever. The need to evaluate the success of adopting the concept of sustainability and assess its impacts from social, environmental and economic perspectives provide manufacturers with the realization of various benefits.

In this study, a multi-criteria decision making method, TOPSIS, is adopted in a real life case study to assess the manufacturing sustainability of an international beverage company which produces non-alcoholic drinks, using various conflicting sustainability indicators simultaneously. The method used has several advantages such as the application practicability and simplicity. Although a large number of indictors exist in the literature, in this study a limited number of them were adopted as the existing data collected by the company is restricted.

References

Hwang C, Yoon K (1981) Multiple attribute decision making: methods and applications. Springer-Verlag, New York

Joung CB, Carrell J, Sarkar P, Feng SC (2013) Categorization of indicators for sustainable manufacturing. Ecol Ind 24:148–157

Krajnc D, Glavic P (2003) Indicators of sustainable production. Clean Technol Environ Policy 5:279–288

Ness B, Urbel-Piirsalu E, Anderberg S, Olsson L (2007) Categorising tools for sustainability assessment. Ecol Econ 60:498–508

Organization for Economic Co-operation and Development—OECD (n.d.) Sustainable manufacturing indicators. Retrieved at 14 Sept 2013 from http://www.oecd.org/document/48/0,3746,en_21571361_47075996_47855728_1_1_1_1,00.html

Raizer-Neto E, Mariotte MT, Hinz RTP (2006) Indicators to measure sustainability of an industrial manufacturing. Innov Life Cycle Eng Sustain Dev 18:111–122

Rao VR (2007) Decision making in the manufacturing environment. Springer-Verlag, London

Rennings K, Wiggering H (1997) Steps towards indicators of sustainable development: linking economic and ecological concepts. Ecol Econ 20(1):25–36

United Nations (August 04, 1987). Report of the World Commission on environment and development: our common future/general assembly resolution 42/427. Retrieved at Sept 2015 from http://www.un-documents.net/k-002988.htm

United Nations (December 19, 1983). Report of the World Commission on environment and development: process of preparation of the environmental perspective to the year 2000 and beyond/general assembly resolution 38/161. Retrieved at Sept 2015 from http://www.un-documents.net/a38r161.htm

Veleva V, Ellenbecker M (2001) Indicators of sustainable production: framework and methodology. J Clean Prod 9:519–549

Warhust A (2002) Sustainability indicators and sustainability performance management. University of Warwick, Warnick

Wiktorsson M, Bellgran M, Jackson M (2008) Sustainable manufacturing—challenges and possibilities for research and industry from a Swedish perspective. Manuf Sys and Technol New Frontier 16:119–122