DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

MULTI-CRITERIA SUSTAINABILITY ASSESSMENT OF ENVIRONMANTALLY CONSCIOUS MANUFACTURING COMPANIES - A CASE STUDY IN BEVERAGE INDUSTRY

by
Merve KILIÇ

February, 2014
İZMİR

MULTI-CRITERIA SUSTAINABILITY ASSESSMENT OF ENVIRONMANTALLY CONSCIOUS MANUFACTURING COMPANIES - A CASE STUDY IN BEVERAGE INDUSTRY

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by
Merve KILIÇ

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled "**MULTI-CRITERIA SUSTAINABILITY ASSESSMENT OF ENVIRONMANTALLY CONCIOUS MANUFACTURING COMPANIES - A CASE STUDY IN BEVERAGE INDUSTRY**" completed by **MERVE KILIÇ** under supervision of **ASST. PROF. DR. SEREN ÖZMEHMET TAŞAN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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MULTI-CRITERIA SUSTAINABILITY ASSESSMENT OF ENVIRONMANTALLY CONSCIOUS MANUFACTURING COMPANIES - A CASE STUDY IN BEVERAGE INDUSTRY

ABSTRACT

In a manufacturing environment, managing limited resources has always been a critical issue. Recently, the idea of managing limited resources without harming ecological environment adopted by manufacturing sector and sustainable manufacturing has become a key issue. The importance of the sustainable manufacturing has been increased rapidly, companies show tendency to adopt this concept. While the concept of sustainability has been recognized by manufacturers, companies need to measure how sustainable they perform. Therefore, sustainability indicators are developed and used in order to assess companies' production activities expediently to sustainable manufacturing. However, sustainability can be thought as an abstract issue which is hard to measure and also assess. Practically, various indicators should be considered simultaneously while evaluating the sustainability performance of a manufacturing system. However, recent researches generally focused on determining suitable indicators and developing assessment methods for manufacturing systems. Hence there is a lack of study considering the application of the assessment methods using sustainability indicators. In order to fill this gap, this thesis focuses on the usage of sustainability indicators to assess the sustainability of a production company from a multi-criteria decision making point of view.

In this thesis TOPSIS method is adopted as an assessment method with the use of several conflicting indicators simultaneously. In TOPSIS method, only the sustainability indicators related to product are the main focus. Furthermore, to illustrate the application of TOPSIS method, two example problems are used and later, this method is applied to assess the sustainability of several case studies belonging to a company in beverage industry.

Keywords: Sustainability, TOPSIS, sustainability indicators, sustainable manufacturing, performance assessment

ÇEVRESEL OLARAK BİLİNÇLİ ÜRETİM ŞİRKETLERİNDE ÇOK KRİTERLİ SÜRDÜRÜLEBİLİRLİK DEĞERLENDİRMESİ – İÇECEK ENDÜSTRİSİNDE BİR VAKA ÇALIŞMASI

ÖZ

İmalat sistemlerinde kıt kaynakların yönetimi her zaman kritik bir konu olmuştur. Son zamanlarda kıt kaynakların çevreye zarar vermeden kullanılması fikri imalat sektörü tarafından benimsenmeye başlamış ve sürdürülebilir imalat anlayışı temel mesele haline gelmiştir. Sürdürülebilir imalatın önemi arttıkça firmalar tarafından git gide daha çok benimsenmiş ve firma aktivitelerinin bu kavrama göre ölçümlenmesi ihtiyacı doğmuştur. Böylece, sürdürülebilir imalat anlayışına uygun bir şekilde üretim aktivitelerinin değerlendirilebilmesi için indikatörlerin geliştirilip kullanılması söz konusu olmuştur. Ancak, sürdürülebilirlik bir bakıma soyut bir kavram olduğu için, ölçülmesi ve değerlendirmesi konusunda bir takım zorluklar oluşmaktadır. Bir imalat sisteminde değerlendirme yaparken, çok sayıda indikatörün beraber ele alınması gerekmektedir ki çoğu zaman bu indikatörler arasında bir çatışma gözlemlenir. Son dönemlerde yapılan çalışmalarda, uygun indikatörlerin belirlenmesi ve değerlendirme yapabilmek adına metotlar geliştirilmesi konuları ayrı ayrı ele alınmıştır. Bundan dolayı, geliştirilen indikatörlerin değerlendirme metotlarında kullanılmasıyla ilgili olarak literatürde yeterli sayıda çalışma yoktur. Bu sebeple, bu tez çalışması, sürdürülebilirlik indikatörlerini bir değerlendirme yönteminde kullanarak imalat sektöründeki bir firmanın çok kriterli değerlendirmesini yapmayı amaçlamaktadır.

Bu tez çalışmasında değerlendirme metodu olarak TOPSIS yöntemi, çatışma içerisindeki çeşitli sürdürülebilirlik indikatörleri eş zamanlı kullanılarak uygulanmıştır. Uygulamada sürdürülebilirlik indikatörlerinden sadece üretim için belirlenmiş olanları kullanılmıştır. Ayrıca, TOPSIS metodunun bu konuda kullanımını izah edebilmek için iki adet örnek problem tasarlanmış ve sonrasında içecek sektöründeki bir şirketin değerlendirilmesi için altı adet örnek olay incelemesi yapılmıştır.

Anahtar Kelimeler: Sürdürülebilirlik, TOPSIS, sürdürülebilirlik indikatörleri, sürdürülebilir imalat, performans değerlendirmesi.

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CHAPTER ONE
INTRODUCTION

After the World War II, development efforts are accelerated for many countries and as a result the industrial and technological growth became main focus. Since the manufacturing activities are the key issues for industrialization for attempt of reaching economic developments, our world is threatened ever more by the environmental problems. Improvements in industry, communication and transportation increase the density of economic, political, cultural and social interactions between countries in the world and societies became more open to be affected by each other's activities. Since our world became global, global industrial activities have caused environmental issues which bring along a need to establish balance between development and environment. The term sustainability was born as an outcome of the need to take action against negative effects resulting from the globalization and development activities.

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 the importance of additional efforts for increasing the environmental investments will provide sustainable development. Since the main issue is poverty and environment in developing countries, the main focus to decrease poverty, to ease the access to the market and increase the educational and health care systems in the concept of sustainable development. Differently from developing countries, developed countries are mainly focusing the aspects of protecting environment and sustaining the welfare of the community (Kaypak, 2011).

It is widely accepted that manufacturing is the backbone of the industrialization process. Consumption of the natural resources and creating pollution are the main environmental problem caused by manufacturing activities. Additionally, manufacturing industries have been faced with increasing costs and creating adding value for customers. These conditions intensify competition in the market and create economic pressure for manufacturers. Moreover, these conditions bring the need to change the conventional cost orientation paradigms to competition adding value and

sustainability (Westkamper, 2008). Along environmental concerns and competitive market conditions, using the resources efficiently has always been the core issue for manufacturing. Under these circumstances, the interest to manufacturing in a sustainable way has ever increased in industry as in countries (Millar & Russel, 2011). The importance and the impact of sustainability have been realized by companies which are willing to survive in competitive market and succeed in business financially.

Determining the companies' position in market and evaluating the success in business, the financial parameters are generally considered in order to provide information. With this sense, indicators which are developed for a specific purpose to provide information about parameters are used. With the ever increasing interest in sustainable manufacturing, it become necessary to measure and evaluate sustainability for a company similar to approach to evaluating business success. Hence, sustainability indicators are developed with the same sense of financial indicators and utilized to measure the success of the company in the concept of sustainability and sustainable manufacturing (Veleva & Ellenbecker, 2001). However, the concept of sustainability is as an abstract issue which is hard to measure. Despite the vagueness of the concept, indicators serve to monitor and assess to environmental impacts of manufacturing activities. (Warhust, 2002). Since the concept of sustainability contains "trade-offs" inherently, indicators may have effects on each other. Therefore, it is possible to observe negative change in one indicator while the other one change positively.

Since, the interest to evaluate the success in sustainability has increased in recent years, assessment of sustainability in manufacturing environment acquire the attention of researchers. Consequently, besides creating indicators to address the sustainability metrics, developing and designing the measurement methods become an attracted point of order for researchers. However, due to difficulties in determining suitable indicator baseline, there has been a lack of research concerning performance evaluations by using indicators. In this area, there is a very limited number of researches developed (Gerbens-Leenes, Moll & Schoot-Uiterkamp, 2003; Tao & Hung, 2003; Kolak, Akın, Birbil, Feyzioğlu & Noyan, 2011).

Since the environmental problems come up ever more, the manufacturers faced with the responsibilities regarding consumption natural resources and producing their goods without harming the nature. Inevitably, the term sustainability and sustainable manufacturing has gained importance ever more. As a result, the progress of manufacturing in a sustainable way created the need for companies' to evaluate and assess their impact to environment. Hence, creating and defining indicators to determining sustainability efforts of companies' become the priority for researchers because of the vagueness sustainability concept. Since the utmost importance is given to determining indicators, there has been a lack of studies including the performance evaluations using the indicators. In order to fill this gap, this thesis focuses on the usage of sustainability indicators to assess the sustainability of a production company from a multi-criteria decision making point of view. This thesis presents only the sustainability indicators related to product. In particular, this thesis contributes to the field by applying the TOPSIS method as an assessment method with the use of several conflicting indicators simultaneously. Furthermore, to illustrate the application of TOPSIS method, two example problems are used and later, the proposed TOPSIS method is applied to assess the sustainability of several case studies belonging to Coca-Cola Company.

The structure of the thesis is as follows: chapter two provides better understanding regarding the terms sustainability and sustainable manufacturing. Chapter three includes the extensive literature review of the sustainability indicators. Chapter four contains information about sustainability assessment methods. Chapter five covers TOPSIS method and provides wider understanding by examples. Chapter six presents the case studies with several sustainability indicators derived from Coca-Cola Company's data. Finally, the findings are discussed and concluded in chapter seven.

CHAPTER TWO
SUSTAINABILITY

2.1 Key Issues in Sustainability

In ecology, *sustainability* is defined as the providing the continuousness of biological systems' variety and productivity. Considering this definition, the term of sustainability can be used for managing the resources via long term maintenance of responsibility for environment, economy and society. Sustainability can be evaluated as a problem statement that seeks ways for human and other forms of life will flourish on the planet forever.

Since the fundamental object is to sustain human life and keep planet in a way that every generation can be live, sustainable development is the main concern in the concept of sustainability. WCED, known as the Brundtland Commission's 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. Besides, it is also reserved utilization of resources, direction of investments, technological development and institutional change.

2.2 Sustainable Manufacturing

Efficient use of resources has always been the one of the main concerns of manufacturing activities. Recently, the focus of environmental issues has merged with the concerns regarding the using resources efficiently and created the need for sustainability in industry. Besides, demands for product have been increased globally. Manufacturing in a sustainable way and meeting the globally increasing product demand together bring a great need for industry seeking technology and strategies to

reduce globally the environmental impact from manufacturing (Wiktorsson, Bellgran & Jackson, 2008).

With the ever increasing interest in sustainability, the companies started to realize the importance and impact of manufacturing their products in a more sustainable way. *Sustainable manufacturing* refers to that decreasing the negative effects of a product and its production processes on environment, health and welfare of community to minimum level. From raw material to the finished good and even at the recycling phase, the product should cause no or minimum damage to environment and during its production process, environmental resources should be used efficiently. Hence, environmentally conscious manufacturing can be reviewed at the two levels such as product and process focuses. Product focus refers that developing products considering the minimum negative effect on environment and process focus considers decreasing the environmental impact while manufacturing products.

Manufacturing actions considering the environmental issues also contributes to firms as advantages in competitive market environment. Because the actions concern the environment includes typically the product and process focus which are useful to derive value improvement and cost decrease (Wiktorsson et al., 2008)

The objectives of sustainable manufacturing are defined by the European Union as creating more value for more growth and better jobs, increasing the competition of European industries and the communities in the knowledge century and sustainable development of economies (Westkamper, 2008). Since the importance of the sustainable manufacturing has been increased rapidly, companies show tendency to adopt this concept. Similar to companies' approach which uses financial indicators to determining the business success, there has been needed to measure and evaluate sustainability. However, sustainability can be thought as an abstract concept which is hard to measure. Therefore sustainability indicators are developed and used in order to measure how a company succeeds in the concept of sustainability and sustainable production.

Several researchers have focused on determining indicators related sustainable manufacturing (OECD n.d.; Raizer-Neto, Mariotte & Hinz, 2006; Krajnc & Glavic, 2003). These researchers gave utmost importance to create and define new sustainable manufacturing indicators. However, due to difficulties in determining suitable indicator baseline, there has been a lack of research concerning performance evaluations by using indicators. Practically, various indicators should be considered simultaneously while evaluating the sustainability performance of a manufacturing system. In order to fill this gap, the contribution of this thesis focuses on the application of TOPSIS method that makes us able to consider various sustainability indicators simultaneously. Further information about sustainability indicators for production and assessment of sustainability are given in Chapter 3 and 4 consecutively.

CHAPTER THREE
LITERATURE REVIEW: SUSTAINABILITY INDICATORS FOR PRODUCTION

Organization for Economic Co-operation and Development (OECD) defined an indicator in 1993 as a parameter or a value derived from parameters, which provides information about a phenomenon. The indicator has significance that extends beyond the properties directly associated with the parameter values. Indicators possess a synthetic meaning and are developed for a specific purpose.

Sustainable development is abstract concept for many researchers but it is quantified in many studies to be workable by determining indicators. United Nations (UN) defined indicators for sustainable development considering sociological field of development problems as well as the physical problems (UN, 2007). United Nations Commission on Sustainable Development (UNCSD) grouped indicators according to the four pillars of sustainable development; social, economic, environmental and institutional considering 44 sub-themes related to fields such as poverty, governance, health, education, demographics, natural hazards, atmosphere, land, oceans, seas and coasts, freshwater, biodiversity, economic development, global economic partnership, consumption, and production patterns (see Figure 3.1).

Similar to companies' approach which uses financial indicators to determining the business success, there has been needed to determine and define sustainability indicators in order to measure how a company succeed in the concept of sustainability and sustainable production

In literature, sustainability indicators related to manufacturing are evaluated in three differently named groups such as product, process and management (Raizer-Neto et al., 2006), social, environmental and economic (Krajnc & Glavic, 2003) or inputs, operations and products (OECD, n.d.). This thesis presents only the indicators related to product.

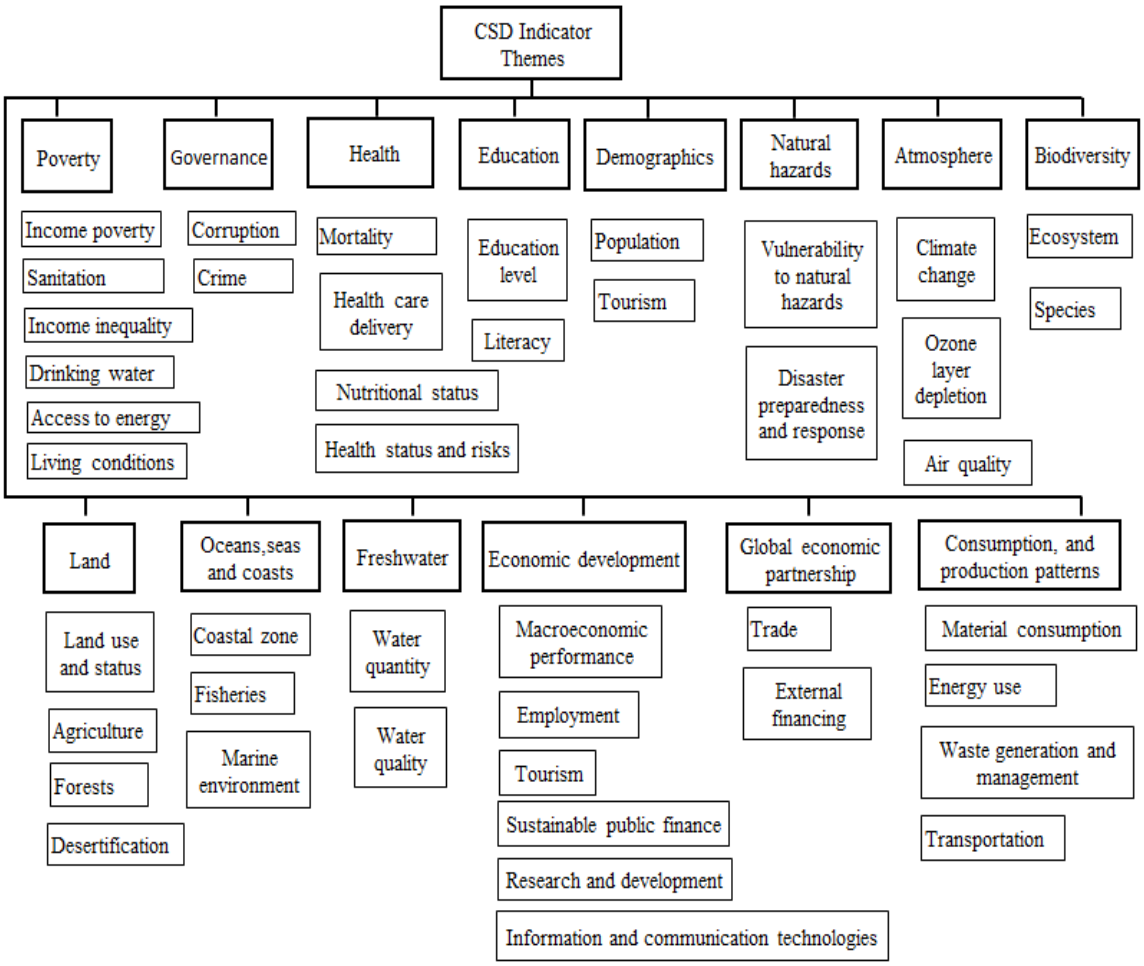


Figure 3.1 UNCSD theme indicator framework

Product indicators generally state the impacts of materials used for producing the product, consumption and renewability of the resources used for production and recyclability of a product.

Raizer-Neto et al. (2006) defined nine indicators related to product considering the material usage and renewability, usage of resources such as energy and water and transportation of material and products. They establish product indicators by using three subtitles which are production, uses and function (see Figure 3.2).

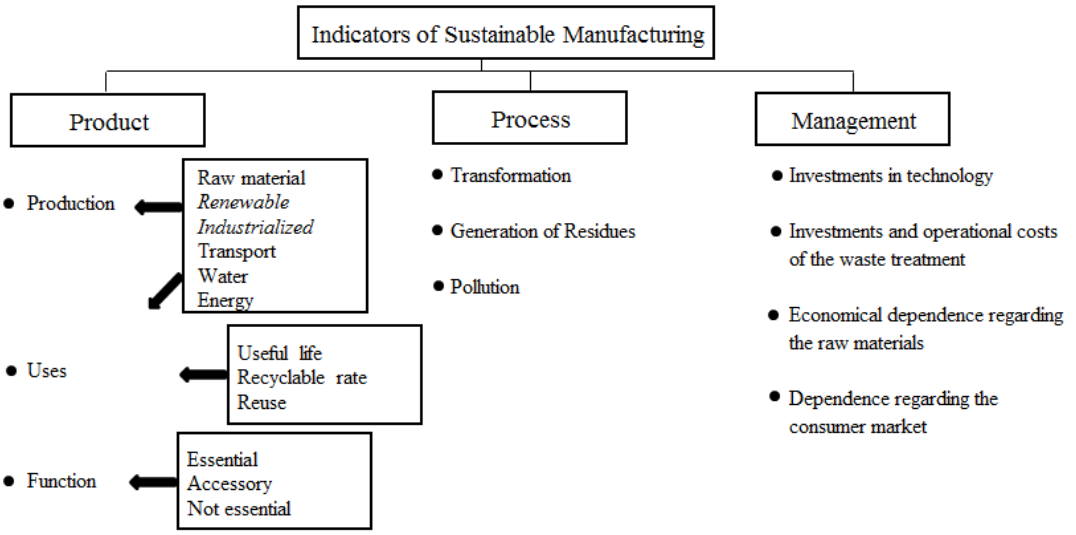


Figure 3.2 Indicators defined by Raizer-Neto et al.

OECD defined product indicators related to materials with the aspects of renewable and non-renewable and also with the content of restricted substance. Energy consumption is also included in to indicators. Additionally, greenhouse gas emission intensity is mentioned (see Figure 3.3).

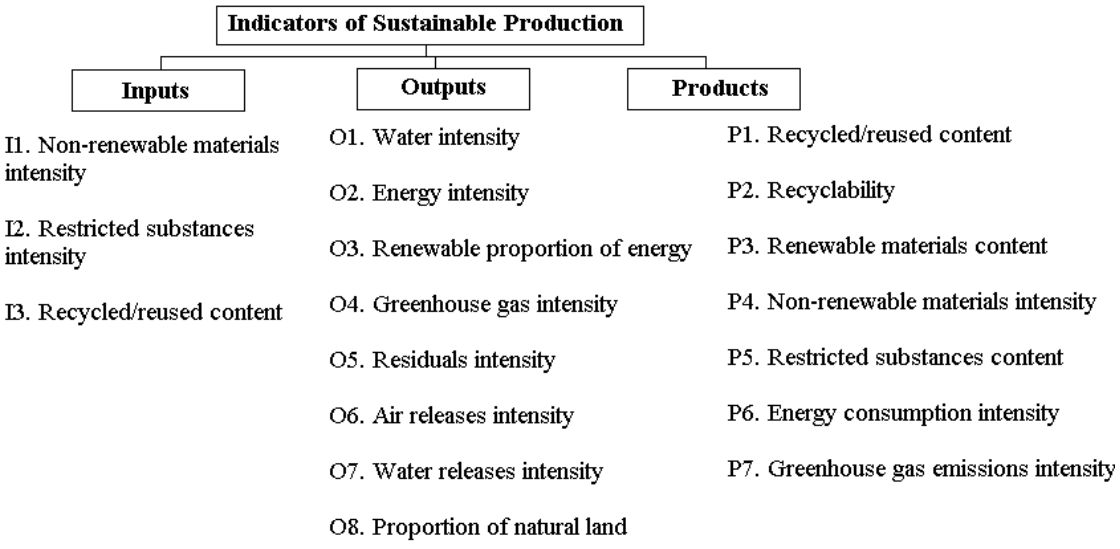


Figure 3.3Sustainable manufacturing indicators defined by OECD

The majority of the OECD's sustainable manufacturing indicators are normalized. Instead of using the total amount, the indicators are presented in relative terms as a ratio of performance per specific unit of output. It means that, instead of simply reporting a total amount, the indicator for water intensity, for example, is defined as water consumption per unit of output from facility.

Krajnc & Glavic (2003) defined product indicators under the output indicators which is a branch of the main title of the environmental indicators. Their study also mentioned the recyclable materials. It differs from other studies with the aspects of revenue from the eco products, durability of a product and costs and recycling of packages (see Figure 3.4).

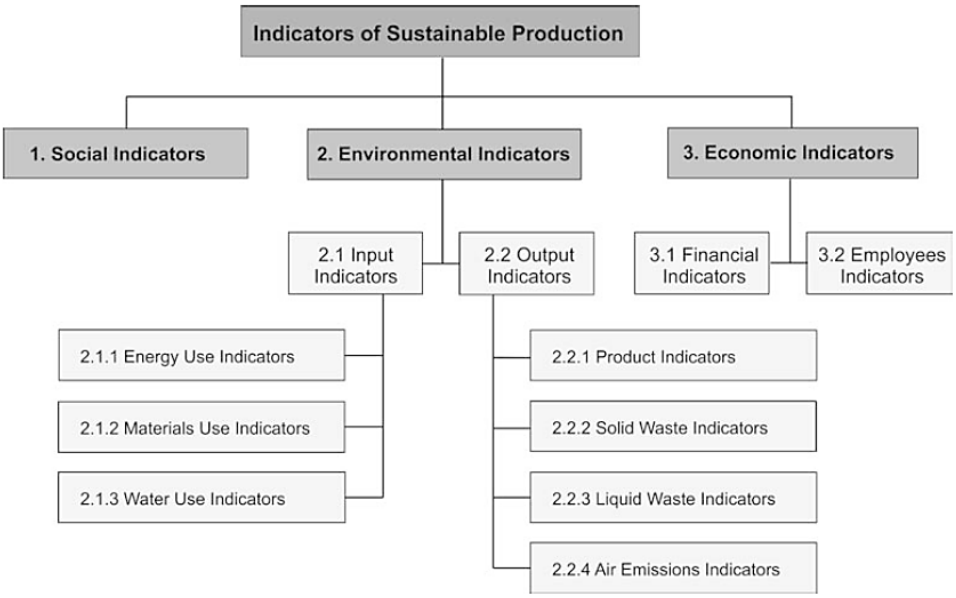


Figure 3.4 Sustainable production indicators by Krajnc & Glavic

Since most of the production indicators introduced above have conflicting values, assessment using simple calculation methods becomes useless and inefficient. Therefore, in this thesis, TOPSIS method has been used to solve this multi-criteria decision problem while considering the trade-offs between product indicators.

CHAPTER FOUR
LITERATURE REVIEW: ASSESSMENT OF SUSTAINABILITY

4.1 Introduction

Sustainability assessment can be defined as self-assessment for an organization in the direction of their economic, social and environmental responsibilities. Recently, sustainability assessment become as a policy tool whose main objective is to direct planning and decision making towards sustainability.

OECD Sustainable Development Advisor Candice Stevens (n.d.) defines the main steps of sustainability assessment as relevance analysis, scoping analysis, impact analysis, comparative analysis, associative analysis and political analysis.

Since there are numbers of tools that exist and many of them have developed in order to present better applications and case study experiences, it is also necessary to provide a categorization of sustainability assessment tools to develop the broader understanding and wider interpretation of sustainability (Ness, Urbel-Piirsalu, Anderberg & Olsson, 2007). Based on the temporal focus of the assessment tools along with the object of focus of the tool, Ness et al.(2007) proposed a framework that shows the temporal focus, which is either retrospective (indicators/indices), prospective (integrated assessment) or both (product-related assessment). The object of focus of the tools is either spatial, referring to a proposed change in policy (indicators/indices and integrated assessment), or at the product level (product-related assessment). The framework developed by Ness et al. (2007) is shown in Figure 4.1.

Tools for assessing sustainability are mainly considered into groups as economic, environmental and social. Cost/benefit analysis, modeling, regressions and scenarios are generally included in economic section. Life-Cycle analysis, material flows, resource accounting, NAMEA and ecological footprint are evaluated into environmental assessment tools. The last category in sustainability assessment tools depicted as social group implies sustainable livelihoods, human and social capital measurement and participatory processes.

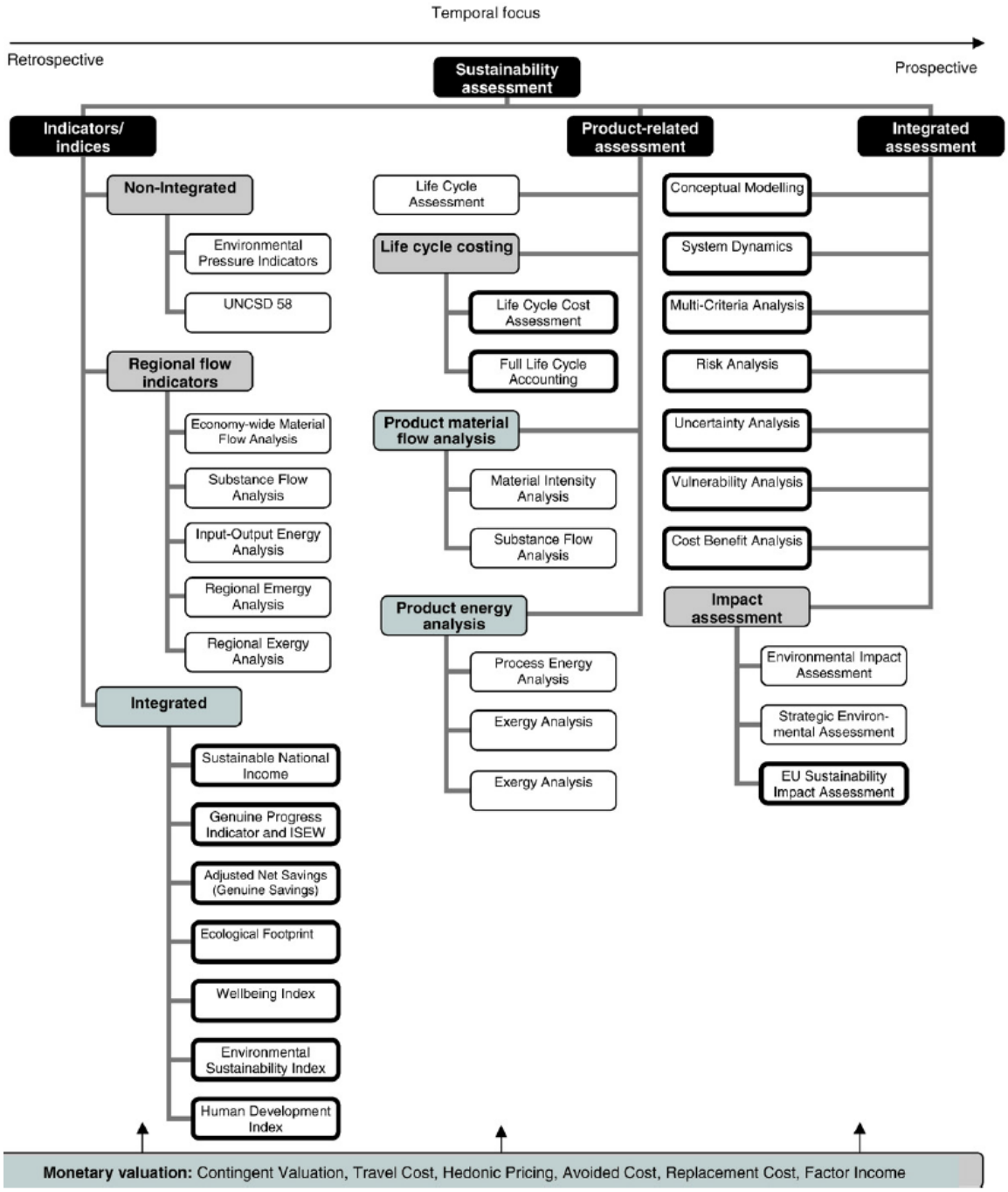


Figure 4.1 Framework for sustainability assessment (Ness et al., 2007)

Some researchers procure elucidations on sustainable assessment by considering the different approaches in literature and evaluate their potential contribution to the subject.

Many of the approaches are expressed as actually examples of ‘integrated assessment’, derived from strategic environmental assessment (SEA) and environmental impact assessment (EIA). Pope et al. claims that they have been extended to incorporate social and economic considerations as well as environmental ones, reflecting a ‘triple bottom line’ (TBL) approach to sustainability. These integrated assessment processes typically either seek to minimize ‘unsustainability’, or to achieve TBL objectives. Both aims may, or may not, result in sustainable practice (Pope, Annandale & Morrison-Saunders, 2004).

4.2 Tools for Sustainability Assessment

In order to provide further perspective to sustainability assessment, commonly used approaches are represented below categories.

4.2.1 Strategic Environmental Assessment (SEA)

In the 1969 US National Environmental Policy Act (NEPA) formally establish the concept of evaluating environmental impacts of policies, plans and programmes because of the requirement of an environmental assessment for proposed federal agency actions, arguably constituting the first formal framework for both environmental impact assessment (EIA) and SEA in the world (Fundingsland & Hanusch, 2012). However, the term ‘strategic environmental assessment’ was first expressed by Wood and Djeddour in the late 1980s in an interim report to the European Commission (Partidário, 2007; Wood & Djeddour, 1989, 1992). Over the years, SEA became recognized as a form of environmental assessment that can assist decision makers in policy, planning and programmatic decisions. SEA is applied to evaluate and identify potential impacts of policies, plans and programmes and promote more sustainable patterns of development for many fields which are developing rapidly. SEA contributes towards sustainability by providing broader environmental vision, ensuring early consideration of environmental issues, anticipating environmental impacts, facilitating environmentally-oriented chain of actions and also contributes to integrated policy-making and planning.

4.2.2 Environmental Impact Assessment (EIA)

Jay et al defines EIA as an evaluation of the effects resulting from a major project or an action significantly affecting the natural and man-made environment (Jay, Jones, Slinn & Wood, 2007).Identifying, evaluating and mitigating the environmental impacts are the bases to determine the adequacy of an EIA. Environmental Policy Act first introduced EIA in 1969 and over years it has becomes almost a standard requirement and critically important for projects or actions which required major change in land use or located in environmentally sensitive regions. Mainly the focus is environmental but also often addresses social, economic and institutional issues. EIA aims to identify the impacts of proposed public and private development activities not only for beneficial but also negative aspects.

4.2.3 Triple Bottom Line (TBL)

Triple Bottom Line (TBL) also known as 3BL and indicates people, planet and profit or three pillars. From the sustainability assessment perspective it is used for interpreting sustainability that places equal importance on environmental, social and economic considerations in decision-making (Pope et al.,2004). While trying to evaluate the impact of a project or an activity on the environment, population and the attractiveness of the neighborhood of the site, these three aspects should be taken into account.

4.2.4 Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA)

Cost-Benefit Analysis (CBA) and Cost-Effectiveness Analysis (CEA) both aims to minimize costs necessarily to targeted as an achievement of a project or an activity and not for maximizing the advantages. These analyses are simply based on considering the financial equivalent of all the positive and negative impacts of the projects or activity of the organization. These types of analyses are not easy when the researcher aims to provide the impacts of direct external and social costs.

4.2.5 Life Cycle Analysis (LCA) and Life Cycle Sustainability Assessment (LCSA)

Life Cycle Analysis (LCA) is a technique that considers the stages of a product's life cycle commonly defined as cradle-to-grave which term depicts the phases from raw material to the finished good also even the use, repair maintenance and disposal or recycling. LCA provides avoiding the environmental concerns by compiling an inventory of relevant energy and material inputs and environmental releases, evaluating the potential impacts associated with identified inputs and releases and interpreting the results to help make a more informed decision. LCA draws attention arises from the interest in developing methods for addressing the impacts of products along their life cycle and also the increasing awareness of the environmental concerns. Life cycle sustainability assessment (LCSA) approaches to evaluate the impacts of negative and positive from the environmental, social and economic aspects in decision making processes considering product's life cycle with the perspective of sustainability(UNEP/SETAC Life Cycle Initiative, 2011). LCSA also assists to clarify the trade-offs between three aspects of sustainability, product's life-cycle phases and impacts. Moreover it provides wide viewpoint to the negative and positive effects towards product life cycle. However, commonly it cannot procure the satisfied extend to the social aspects.

4.2.6 Optimization Models

Optimization models consists of an objective function and set of constraints in order to select best alternative that minimizes or maximizes the objective function in the system of equations or inequalities. From the sustainability assessment point of view, an optimization model can be used to determine the optimal solution satisfies the social, economic and environmental objectives. In literature optimizations models are used in many areas where social, economic and environmental objectives and constraints can be formulated as well (Chen, G., Chen, B., Dai & Zhou, 2013; Bishop, Amaratunga & Rodriguez, 2007; Zhou, Cheng & Hua, 2000; Al-Sharraha, Elkamel & Almanssoor, 2009).

4.2.7 System Dynamics Models

System Dynamics Models are used for modeling the complex systems. Defining the problems dynamically is the starting phase followed by mapping and modeling phases and proceeds by building confidence in the model and its policy implications. This approach aims to identify the complex systems over time and attends effects on behavior of the entire system in the concepts of internal feedback loops and time delays. From the perspective of sustainability assessment, system dynamics models aim to clarify the relations between sustainability assessment and dynamic systems approach that are proposed as important for improved practices of sustainability assessment. In literature, Musango et al. present combined elements oftechnology development, sustainable development and a dynamic systems approach which are important to evaluate sustainability assessment of technologies and provide the clarification for sustainability technology development, technology assessment, and sustainability assessment and form the basis for a systems approach to technology sustainability assessment (Musango, Brent, Amigun, Pretorius & Muller, 2012).

4.2.8 Assessment Indicator Models

The assessment indicator models use indicators for sustainability assessment. This model can be investigated under three categories such as the composite index model, the multi-level index model and the multi-dimension matrix model (Tao & Hung, 2003). Composite index model produces a single index representing degree of satisfying economic, social and environmental objectives. Green Gross National Product (GNP) index and Index of Sustainable Economic Welfare (ISEW) are the examples of similar indices to measure sustainability. The multi-level index model includes mainly the series of indicator versions that indicate different goals and objectives. The multi-dimension matrix model depicts interactions between different indicators by using logic architectures.

4.2.9 Data Analysis

Data Analysis is the process of reviewing, investigating and modeling data with the intention to support decision making procedure. Models including the data analysis contribute to sustainability assessment by implying the statistical data and applying data analysis techniques such as surveys, hypothesis testing and structural equation modeling.

4.2.10 Multi-Criteria Decision Analysis (MCDA) Methods

In decision making problems MCDA methods support decision makers when there is multiple objectives in the presence of multiple criteria. In multi-criteria decision environment generally these criteria are conflicting (Rao, 2007). In multi-criteria decision making problems, the purpose is not optimizing the solution. In these problems, criteria are evaluated at the same time in order to find compromise solution. The criteria and its outcome must be measurable and valid for every decision alternative. It is also accepted for a criterion to perform at the nominal scale for example satisfying the yes/no or present/absent ratings. In MCDA methods, comparisons are made by evaluating the outcomes of criterion which provide basis for alternatives. Sustainability assessment point of view, MCDA methods provide not only tools but also framework to support the decision maker in order to determine a strategy by integrating tools from other disciplines.

There are many MCDA methods such as Multi-Attribute Value Function Theory (MAVT), Multi Attribute Utility Function Theory (MAUT), Analytic Hierarchy Process (AHP), PROMETHEE, ELECTRE and TOPSIS methods. In this thesis, TOPSIS method is adopted to facilitate the selection of satisfactory alternatives within case studies addressed at the Chapter five.

CHAPTER FIVE
TOPSIS METHOD

5.1 Introduction

TOPSIS stands for Technique for Order Preference by Similarity to Ideal Solution and developed by Hwang and Yoon (1981). Similarly to ELECTRE method, TOPSIS adopted the principle of closeness of the decision points to the ideal solution and compared to the ELECTRE, solution process is shorter.

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 method has several advantages; one of which is the application convenience and simplicity when identifying the suitable alternative quickly. Additionally, it performs similar to various methods that use additive weights and performs better than other methods in most cases.

5.2 Application Steps of TOPSIS Method

The TOPSIS method based on the selected alternative should to be found at the shortest distance from the positive ideal solution and farthest from the negative ideal solution. Positive ideal solution represents the best criteria values and conversely the negative ideal solution represents the worst criteria values attainable from all alternatives. TOPSIS can be summarized in six steps (Figure 5.1). In first step, evaluation matrix is built by listing alternative horizontally and criterion vertically.

Second step consists of dividing each center values by the norm of the total outcome vector in order to non-dimensionalize the center values in the evaluation matrix. Third step includes multiplying the matrix's values by normalized weights of each criterion and establishing the relative importance matrix. The fourth step consists of building positive and negative ideal solutions to compare the alternatives with each other. After determining the positive and negative ideal solutions, the separation of each matrix value from the ideals are measured as Euclidean distances in the fifth step. At the sixth step, these distances are transformed into a single metric called relative closeness to the ideal solution. Finally, alternatives ranked according to their closeness to the ideal solution.

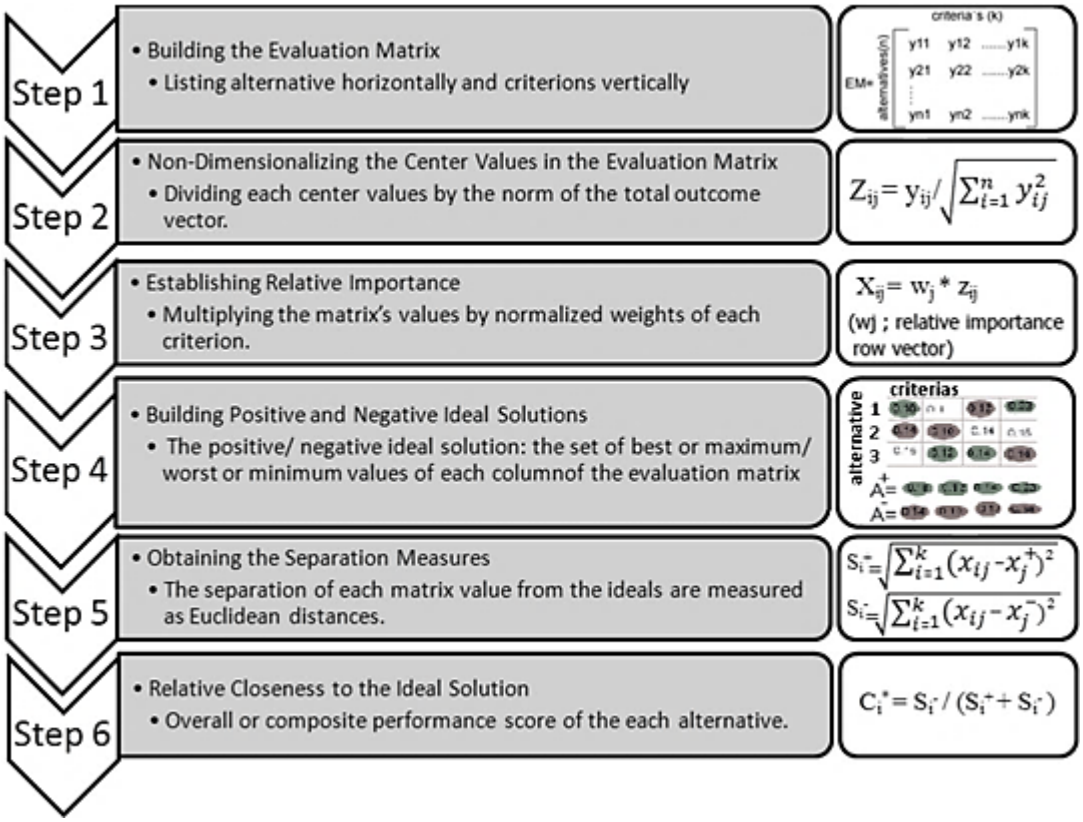


Figure 5.1 Visualizing the steps of TOPSIS method

It is possible for an attribute to be a subjective. In this situation, that attribute can be judged on a scale while assigning weights at the third phase. This subjective attribute is shown on a scale and then the attribute's normalized values are assigned for different alternatives are calculated in the same manner as that for objective attributes.

In decision making problems fuzzy TOPSIS approach is used more often in order to represent significance level of criterion or alternatives in fuzzy numbers instead of certain or absolute values in other word, crisp numbers (Chen &Tsao, 2007).In the phase of assigning weights, decision makers state the importance of the attributes subjectively. Then the process of fuzzy TOPSIS steps to convert these subjective expressions and lend assistance to obtain alternatives in order of distance from ideal solution (Perçin, 2012).

5.3 Examples for Assessment of Sustainability with Production Indicators

For further information about applying the TOPSIS method, two example problems are generated and the steps of the assessment method for each problem are explained together with detailed formulations.

5.3.1 Example 1

For the first example, a scenario is developed according to Company X which has been concerned about sustainability. While producing their ordinary goods the firm decided to enlarge its product range to the new segment: eco-products. During six time periods they have been trying to develop a production strategy related to their sustainability perception. Now Company X wants to eliminate the production of ordinary products and focus on the eco-products. The firm concentrates on three criteria: product durability (I_1), revenues from eco-products (I_2) and reusable packaging mass (I_3). The information is observed related these criteria and examined the six time periods. There were six different strategies in six time periods and now the firm wants to evaluate that which strategy is better.

The first step is building the evaluation matrix includes decision matrix in which the alternatives are in the rows and the evaluation factors are stated in the columns. Figure 5.2 represents the decision matrix where m expresses the numbers of decision points and n shows the numbers of evaluation factors.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix}$$

Figure 5.2 Evaluation matrix

Evaluation matrix includes data of the three criteria regarding the time periods is expressed in Table 5.1 for this case.

Table 5.1 Building the evaluation matrix of example 1

	I_1 (years)	I_2 (million $)	I_3 (tonnes)
P_1: Period 1	5	100	75
P_2: Period 2	6	230	12
P_3: Period 3	7	170	48
P_4: Period 4	6	170	69
P_5: Period 5	8	400	80
P_6: Period 6	8	300	160

Since it is not possible to derive an explicit opinion regarding the alternatives, in such cases it is necessary to use the TOPSIS method to assess in multi criteria decision problems. Figure 5.3 illustrates data recorded for time periods with respect to criteria regarding product durability (I_1), revenues from eco-products (I_2) and reusable packaging mass (I_3). In order to provide broader sight, values of revenues from eco-products (I_2) are divided by 100 and reusable packaging mass (I_3) are divided by 10.

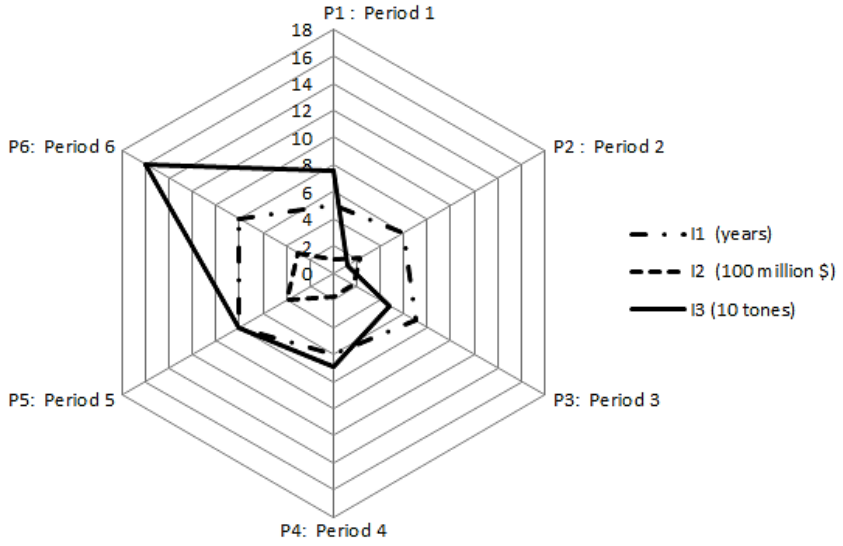


Figure 5.3 Radar graph regarding evaluation matrix.

As a second step is non-dimensionalizing the center values in the evaluation matrix and the related matrix is built based on the formulation 5.1. This matrix is presented in Table 5.2.

$$Z_{ij} = y_{ij} / \sqrt{\sum_{i=1}^{n} y_{ij}^2} \qquad (5.1)$$

Table 5.2 Building the non-dimensional center values in evaluation matrix of example 1

Period P_i	I_1 (years)	I_2 (million \$)	I_3 (tonnes)
P_1	0.3	0.16	0.35
P_2	0.36	0.37	0.05
P_3	0.42	0.27	0.22
P_4	0.36	0.27	0.32
P_5	0.48	0.65	0.37
P_6	0.48	0.49	0,75

The Third step is to establish relative importance. Firstly the weights are determined ($\sum_{j=1}^{n} w_j = 1$). In this step relative importance (w_j) of the criterion consists of multiplication the matrix values by the normalized weights for each criterion. In this

example Normalized weights of the criteria are found with a ten point scale (see Table 5.3).

Table 5.3 Scaling the criterion of example 1

	Points out of 10	Normalized Values
I_1	6	0.32
I_2	8	0.42
I_3	5	0.26
Total	19	1

$$X_{ij}=w_j * z_{ij} \quad (5.2)$$

The matrix representing the relative importance is constructed by using the formula 5.2 which indicates that the each value of the matrix multiplied by the normalized weights of the criteria (see Table 5.4).

Table 5.4 Establishing the relative importance of example 1

Period P_i	I_1 (years)	I_2 (million $)	I_3 (tonnes)
P_1	0.096	0.069	0.093
P_2	0.115	0.159	0.015
P_3	0.134	0.117	0.059
P_4	0.115	0.117	0.086
P_5	0.153	0.278	0.099
P_6	0.153	0.207	0.199

In the fourth step of the method positive and negative ideal solutions are built due to the formulation 5.3. Positive ideal solution set is built based on the choosing the largest value of the column if the related evaluation factor is maximization oriented. Negative ideal solution set is also built in the same manner. In the other words the positive ideal solution corresponds to the set of best or maximum values of each column. Conversely, the negative ideal solution constitutes the set of worst or

minimum values of each column of the evaluation matrix where A^+ and A^- are the set of maximum and minimum values of the criterion.

$$A^* = \left\{ (\max_i x_{ij} \,|\, j \in J), (\min_i x_{ij} \,|\, j \in J') \right\} \text{ and } A^- = \left\{ (\min_i x_{ij} \,|\, j \in J), (\max_i x_{ij} \,|\, j \in J') \right\} \quad (5.3)$$

According to Company X, it is better if a product has maximum durability, consists of more reusable package and with the maximum revenue. Based on these preferences, Table 5.5 includes the values which are selected as the positive ideal solution in bold and negative ideal solution in italic form.

Table 5.5 Building positive and negative ideal solutions of example 1. The data indicates positive ideal solution are shown in bold and negative ideal solution are shown in the italic form.

Period P_i	I_1 (years)	I_2 (million $)	I_3 (tonnes)
P_1	*0.096*	*0.069*	0.093
P_2	0.115	0.159	*0.015*
P_3	0.134	0.117	0.059
P_4	0.115	0.117	0.086
P_5	**0.153**	**0.278**	0.099
P_6	**0.153**	0.207	**0.199**

Maximum value of each criterion: $\mathbf{A^+ = \{}$ 0.153, 0.278, 0.199 **}**

Minimum value of each criterion: $\mathbf{A^- = \{}$ 0.096, 0.069, 0.015**}**

The fifth step is obtaining the separation measures where the separation of each alternative from the ideal one is given by Euclidean distance. Positive separation measure (S_i^*) and negative separation measure (S_i^-) are shown in formula 5.4

$$Si^+ = \sqrt{\sum_{i=1}^{k} (x_{ij} - x_j^+)^2} \quad \text{and} \quad Si^- = \sqrt{\sum_{i=1}^{k} (x_{ij} - x_j^-)^2} \quad (5.4)$$

Separation measures are calculated for Company X as shown in the Table 5.6.

Table 5.6 Separation measures of example 1.

Period P_i	S_i^+	S_i^-	**Period P_i**	S_i^+	S_i^-
P_1	0.24	0.08	**P_4**	0.19	0.08
P_2	0.22	0.09	**P_5**	0.09	0.08
P_3	0.21	0.08	**P_6**	0.07	0.24

The last step is to determine the relative closeness to the ideal solution. Positive and negative separation measures are used by calculating the relative closeness (C_i) for each alternative by using the formulation 5.5

$$C_i = S_i^- / (S_i^+ + S_i^-) \quad (5.5)$$

The value of C_i is between $0 \leq C_i \leq 1$ and $C_i = 1$ shows the absolute closeness of the corresponding alternative to the ideal solution, in the same sense $C_i = 0$ shows the absolute closeness of the corresponding alternative to the negative ideal solution.

For the three compared period of Company X the relative closeness values are obtained as follows: $C_1 = 0.25$, $C_2 = 0.29$, $C_3 = 0.26$, $C_4 = 0.31$, $C_2 = 0.70$ and $C_3 = 0.77$.

After performing the TOPSIS method, the firm evaluated that the strategy applied on the 6th period fits best to the Company X's sustainability perception and the firm decided to continue its production activities with this strategy. Performance criterion of 5th period is very close to period 6. From Table 5.1, it is seen that the durability is achieved in 5th and 6th period to 8 years and revenue obtained from eco-products shows small decrease. It is also seen that the reusable packaging mass is doubled from period 5 to 6. If the firm concentrating on only first 4 periods, it would be difficult to make a choice because the results provided from these periods are very close to each other while data belongs to these periods were varied (see Figure 5.4).

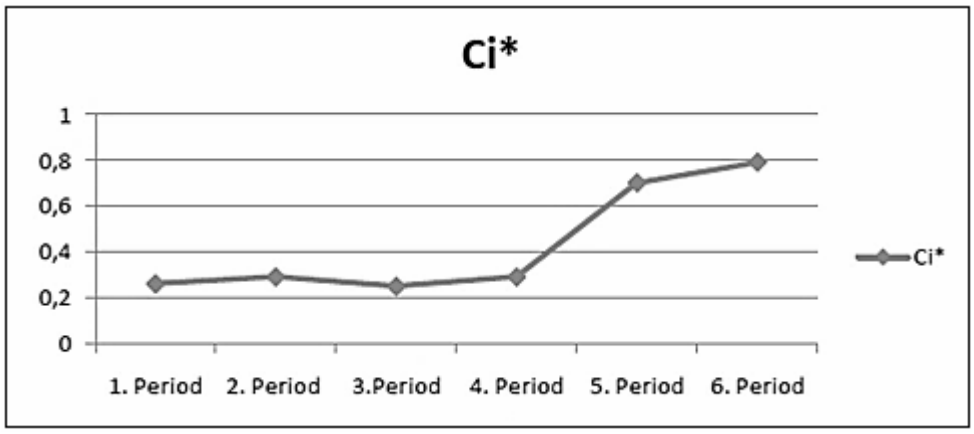


Figure 5.4 Performance values for each criterion

5.3.2 Example 2

In order to develop further understanding, the second example is formed. In this example The Company X wants to determine that which product is matched with the firm's philosophy of sustainability according to data that belongs to products A to the F and shown in Table 5.7

Table 5.7 Information about product A to the F

Products	Demand (yearly)	Price (per product)	Production Duration (of 1 product)	Recyclability (%)	CO_2 Emission (yearly)
A	300	5000	8 hr	75%	25
B	400	3000	11 hr	85%	40
C	200	5000	5 hr	70%	30
D	300	10000	8 hr	50%	45
E	100	20000	12 hr	68%	20
F	600	3000	6 hr	90%	32

The example two shows clearly that the cases include the multiple criteria and alternatives are not easy to observe from data an apparently good or bad alternative. This situation creates the need to use TOPSIS method in order to manage the conflicting criteria (see Figure 5.5).

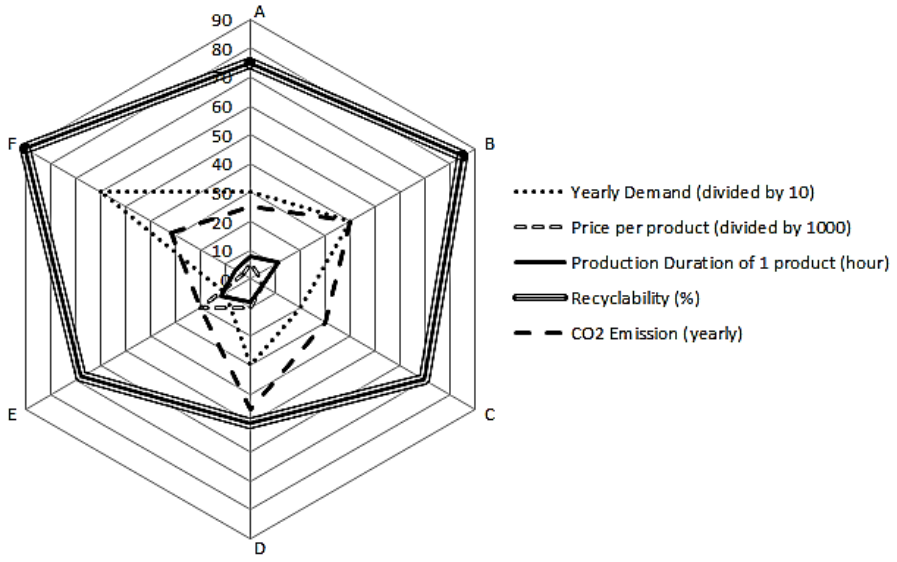


Figure 5.5 Radar graph indicating initial data. Values are simplified in order to provide broader sight

Below calculations and assumptions are made based on the data provided by Table 5.8.

- Annual revenue from product calculated as: for example, product A : 300*5000 = 1500000 and this value is divided by 100000 in order to simplify.
- Revenue from eco-product: 10500000
- Total Revenue of the firm: 19500000
- 24 hr production in a day
- Recycled material costs 600 and normal material costs 1000

Table 5.8 Building evaluation matrix of example 2

Products	**Revenue (I_1)**	**Time (I_2)**	**Recycling (I_3)**	**CO_2 Emission (I_4)**
A	15	8	75	25
B	12	11	85	40
C	10	5	70	30
D	30	8	50	45
E	20	12	68	20
F	18	6	90	32

In the first two steps evaluation matrix is built according to data provided by table 5.7 and the center values in the evaluation matrix are converted to non-dimensional values as well as in the *Example 1* (Table 5.9).

Table 5.9 Non-dimensionalizing the center values in the evaluation matrix of example 2

Products	**Revenue (I_1)**	**Time (I_2)**	**Recycling (I_3)**	**CO_2 Emission (I_4)**
A	0.33	0.37	0.41	0.31
B	0.26	0.52	0.47	0.49
C	0.22	0.23	0.38	0.37
D	0.66	0.37	0.27	0.55
E	0.44	0.56	0.37	0.25
F	0.39	0.28	0.49	0.39

In the third step weights are determined according to following calculations:

- Revenue from eco-products: revenue from eco-products / total revenue : 10.5 / 19.5 =0.54
- 12 hours production in a day and 5 days in a week, 50 hr production of eco-products : 50/60= 0.83
- Recycled material costs 600, normal material costs 1000 : 1000/600= 1.66
  It is assumed that if the firm spends 1000 on normal material, they produce 1 product and if they spends same value on recycled material they produces 1.66 products.
- Mass fraction of greenhouse gases: total mass of CO_2 equivalents/ total mass of products : 192 / 1900 =0.10

Table 5.10 Scaling the criterion of example 2

	Calculated Weights	Normalized Value
I_1	0.54	0.17
I_2	0.83	0.27
I_3	1.66	0.53
I_4	0.10	0.03
Total	3.13	1

After determining the weights for criteria, relative importance matrix is established as well as in the Example 1 (see Table 5.11).

Table 5.11 Establishing relative importance matrix of example 2

Product	**Revenue (I_1)**	**Time (I_2)**	**Recycling (I_3)**	**CO_2 Emission (I_4)**
A	0.056	0.099	0.219	0.009
B	0.045	0.137	0.248	0.015
C	0.038	0.062	0.204	0.011
D	0.113	0.099	0.146	0.017
E	0.075	0.149	0.198	0.007
F	0.068	0.075	0.263	0.012

At the fourth step, positive and negative ideal solutions are determined considering the approach of the firm. According to Company X, the product with the maximum revenue, shortest production time, involves larger amount of recyclable material and with minimum amount of carbon emission is preferable.

Maximum value of each criterion: $\mathbf{A^+ = \{}$ 0.113, 0.062, 0.263, 0.07 $\mathbf{\}}$

Minimum value of each criterion: $\mathbf{A^- = \{}$ 0.037 0.149, 0.146, 0.017$\mathbf{\}}$

The fifth step is to obtain the separation measures. Separation measures for each product are calculated based on the formulation 5.4 (see Table 5.12).

Table 5.12 Separation measures of example 2

Product P_i	S_i^+	S_i^-	**Product P_i**	S_i^+	S_i^-
$\mathbf{P_A}$	0.081	0.091	$\mathbf{P_D}$	0.123	0.090
$\mathbf{P_B}$	0.102	0.103	$\mathbf{P_E}$	0.115	0.065
$\mathbf{P_C}$	0.095	0.105	$\mathbf{P_F}$	0.047	0.142

The sixth also the last step is to obtain the measurement of relative closeness to the ideal solution. By using the formula 5.5, this value is calculated for product A to F as follows: C_A= 0.53, C_B= 0.50, C_C= 0.52, C_D= 0.42, C_E= 0.36, C_F = 0.75

After applying TOPSIS method, it is revealed that product F is the most suitable product alternative for Company X's philosophy of sustainability. If the data is reviewed, it is seen that the product F shows highest performance in production time and recyclability out of remaining products. Moreover production time and recyclability have the highest weights out of the other criteria. It is also seen from the graph shown in Figure 5.6 that products A, B and C show similar performance according to the firm's philosophy of sustainability. If there were a problem of making a choice between those products, it would be difficult for decision maker to decide.

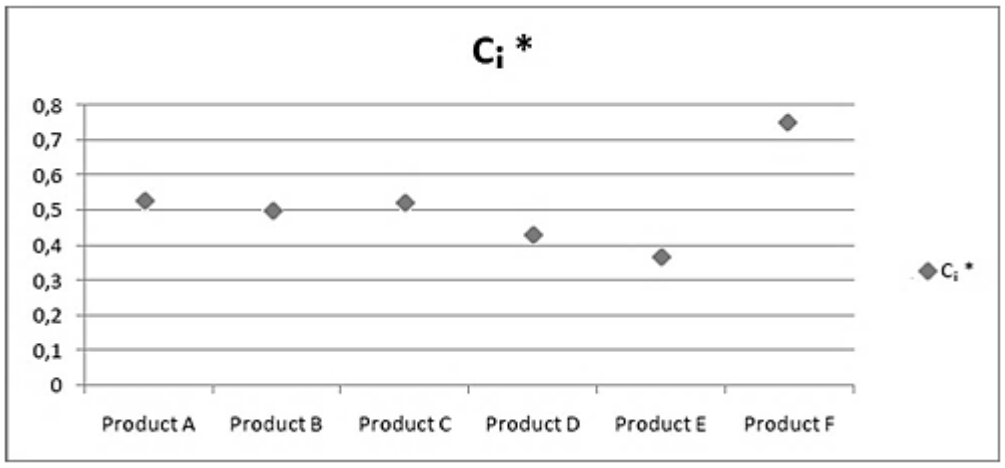


Figure 5.6 Performance values for each product

CHAPTER SIX
CASE STUDIES IN COCA-COLA COMPANY

Coca-Cola is the globally known brand of carbonated soft drink which was created by John Pemberton in 1886. The Coca-Cola Company took todays name and became a corporation in 1892. Today the Coca-Cola system involves the Coca-Cola company and more than 250 bottling partners worldwide. The company manages operations in five main area to understand better in terms of collect analyze data. Areas categorized as Eurasia & Africa, Europe, Latin America, North America and Pacific.

The primary focus of these real world case studies is Coca-Cola İçecek Corporate (CCI). Coca-Cola entered to Turkey's market first in 1964. First factory of Coca-Cola Turkey started to production in 16th September 1964. Later CCI is formed. CCI is the 6th largest bottler in Coca-Cola system and included in Eurasia & Africa area. Today CCI has operations in Turkey, Pakistan, Kazakhstan, Azerbaijan, Kyrgyzstan, Turkmenistan, Jordan, Iraq, Syria and Tajikistan (see Figure 6.1), headquartered in Turkey. Further information can be found athttp://www.cci.com.tr/tr/

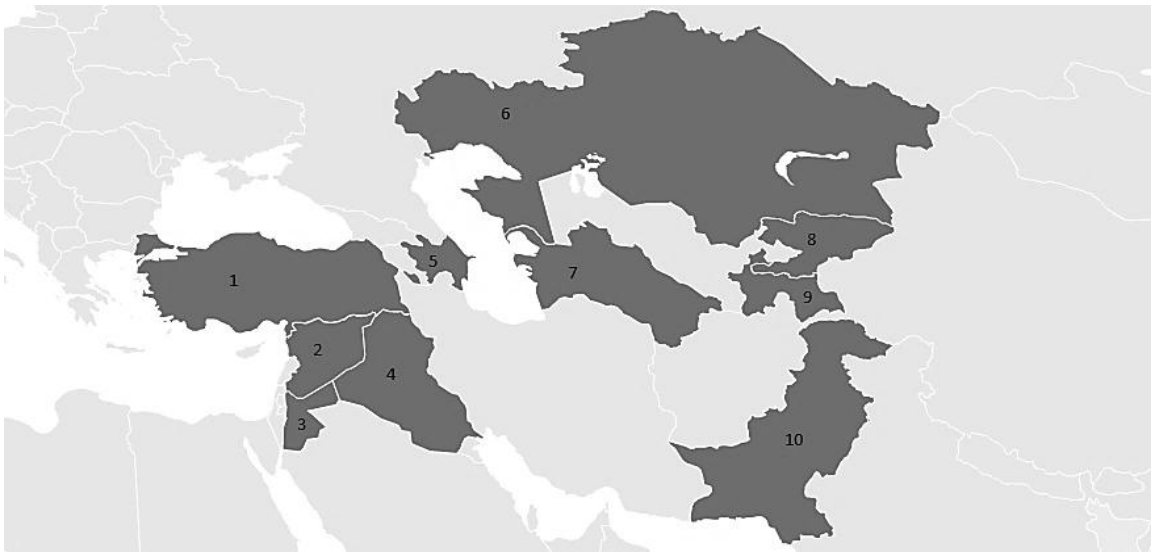


Figure 6.1 CCI Geography: 1-Turkey, 2-Syria, 3-Jordan, 4-Iraq, 5-Azerbaijan, 6-Kazakhstan, 7-Turkmenistan, 8-Kyrgyzstan, 9-Tajikistan, 10-Pakistan

Six case studies have been performed for the multi-criteria sustainability assessment of CCI using several sustainability indicators. The first case study investigates CCI Turkey over years. The second case study contains analysis of factories in six cities of Turkey. The third case study includes assessment of CCI Kazakhstan over years. The fourth case study is on CCI Jordan, similar to the cases that investigate CCI Turkey and Kazakhstan. The fifth case study is comparison of CCI Turkey, Kazakhstan, Jordan and Azerbaijan. And the last case study compares CCI Turkey and Coca Cola system. The variables used in the case studies are as follows; $I_{i,j}$ indicates the j^{th} sustainability indicator used for i^{th} case study. $C_{i,j}$ indicates the j^{th} performance criterion used for i^{th} case study. In the situations that requires different notations are explained in relevant cases particularly.

6.1 Implementation of TOPSIS Method to CCI Turkey over Years

This part of the study concentrates on the Turkey which is the one of the CCI countries and analyzes the sustainability regarding the manufacturing activities. Financial, sustainability and social responsibility reports of CCI are investigated to collect data by developing the study. Table 6.1 and 6.2 contain data from 2003 to 2012 where available information is provided.

Table 6.1 Data of CCI Turkey derived from CCI reports

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Water Use Ratio (L/L)			1.754	1.738	1.624	1.48	1.5	1.42	1.42	1.4
Water Use Amount (m3)					3245934	3378077	3415891	3558449	3850537	
Energy Use Ratio (MJ/L)			0.274	0.26	0.258	0.233	0.23	0.22	0.255	0.252
Solid Waste Ratio (g/L)			3.836	3.899	3.574	3.237	3.11	2.94	3.38	
Recycling Ratio (%)			91.26	90.99	90.14	90.56	93.5	94.41	94.95	96
CO_2 Emission Ratio(g/L)		30.14	28.36	26.05	24.2	23	28.97	28.95	30.1	
CO2 Amount(kg)	45510000	47936000	47289000	48374000	53161974					
Production Amount (L)	1509798000	1690287000	1815511000	1998615000	2279985375					
Total Waste (thousand ton)					7.144	7.373	7.082	7.244	7.211	
Total Shipping Emissions(g/L)					142.77	128.71	13.88	11.92	15.57	
Combustible Use Ratio for Shipping (L/KL)					6.38	6.37	5.05	4.34	5,67	
Sales Volume (million unit box)	221	275			382	420.8	438.9	494.4	546.8	568.5
Net Sales (million TL)					1600	1857.3	1868.2	2.121,40	2.472,80	2757.6
Total Working Hour						3228118	8181012	10324726	9405144	
Total Number of Employees						2220	2633	2659	2820	

Table 6.2 Data indicates direct energy used amount from primary energy resources

	2007	**2008**	**2009**	**2010**	**2011**
Heavy Fuel Oil	17.23	0.28	0	0	0
Light Fuel Oil	5.55	20.75	4.24	5.36	5.57
Propane	76.37	58.6	53.87	57.55	62.91
Natural Gase	161.8	167.48	153.38	141.05	232.73
Total	260.95	247.11	211.49	203.96	301.21

After revealing the all relevant data from the reports, suitable indicators are chosen considering the applicability. The indicators and their indicated meanings are presented in the Table 6.3.

Table 6.3 Indicators and their expressions

$I_{1,1}$	**Water use ratio (L/L)**	Water used per produced amount of liter
$I_{1,2}$	**Water intensity**	Total water consumed/Net sales
$I_{1,3}$	**Specific water consumption (million m^3/million unit box)**	Water use amount/Sales volume
$I_{1,4}$	**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
$I_{1,6}$	**Energy intensity (million MJ/million TL)**	Total energy consumed/Net Sales
$I_{1,7}$	**Solid waste ratio (g/L)**	Solid waste per liter produced
$I_{1,8}$	**Specific solid waste mass (thousand ton/million unit box)**	Total solid waste/Sales volume
$I_{1,9}$	**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)**	Emission per produced liter
$I_{1,12}$	**Combustible use ratio for shipping (L/KL)**	Combustible used/Produced amount of liter

While determining the indicators the data regarding the CCI Turkey provided by reports are evaluated. Reports provide data generally in the form of ratio which enables us to constitute the suitable indicator baseline. Rests of the indicators are

developed based upon the study of indicators of sustainable production by Krajnc & Glavic (2003).

Since some of the data presented in Table 6.1 are non-applicable in terms of persistence, only data between 2007 and 2011 is used. TOPSIS method is used to evaluate the company's progress in terms of sustainability by years. Evaluation matrix is built base on these conditions and Table 6.4 shows the evaluation matrix of years from 2007 to 2011due to the indicators from $I_{1,1}$ to $I_{1,12}$.

Table 6.4 Evaluation matrix

	$I_{1,1}$	$I_{1,2}$	$I_{1,3}$	$I_{1,4}$	$I_{1,5}$	$I_{1,6}$	$I_{1,7}$	$I_{1,8}$	$I_{1,9}$	$I_{1,10}$	$I_{1,11}$	$I_{1,12}$
2007	0.487	0.507	0.538	0.481	0.553	0.572	0.491	0.533	0.434	0.398	0.737	0.508
2008	0.444	0.455	0.508	0.435	0.479	0.465	0.445	0.477	0.437	0.378	0.664	0.507
2009	0.450	0.457	0.492	0.429	0.39	0.393	0.427	0.449	0.451	0.476	0.072	0.402
2010	0.426	0.419	0.456	0.410	0.333	0.343	0.404	0.393	0.455	0.476	0.062	0.345
2011	0.426	0.389	0.044	0.476	0.447	0.429	0.464	0.365	0.458	0.495	0.080	0.451

The necessity to use a multi-criteria decision method is realized if the Table 6.1 is investigated. Figure 6.2 illustrates this table where corresponding criteria are observed in contradictions in terms of objectives. In other words, information regarding the production amounts, outputs and sales ratio mainly represents the different scopes. For instance, the sale volume is desired to be at the highest level as much as possible. On the other hand, the resource usage such as energy, raw material and water consumption is expected to be at lower levels. Thus the indicators representing those criteria are conflicting. Consequently, TOPSIS method is convenient multi-criteria decision making method in terms of simplicity and applicability

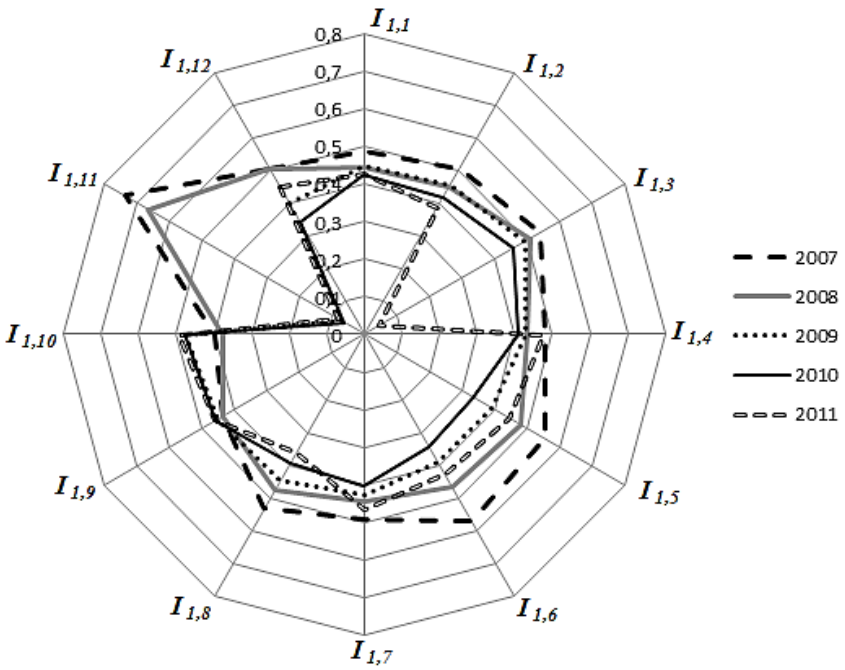


Figure 6.2 Radar graph indicating conflicting indicators.

While applying the TOPSIS method, weights are set regarding the comparison of unit price of energy and water usage, solid waste disposal prices, emission limit values and penalty prices for exceeding those limits. Weights are given as points out of 100 and normalized.

As a result of TOPSIS method, performance of CCI Turkey is obtained by years due to indicators (see Table 6.5).

Table 6.5 Results of performance over years

Years	**Performance Criterion $C_{1,j}$**
2007	$C_{1,1}$: 0.06536
2008	$C_{1,2}$: 0.24183
2009	$C_{1,3}$: 0.54154
2010	$C_{1,4}$: 0,61542
2011	$C_{1,5}$: 0.73468

Figure 6.3 represent the improvement of CCI Turkey over years. If the data is reviewed, it is seen that the usage of resources tried to be minimized over years while the sales and incomes are increased due to the raise of production amounts.

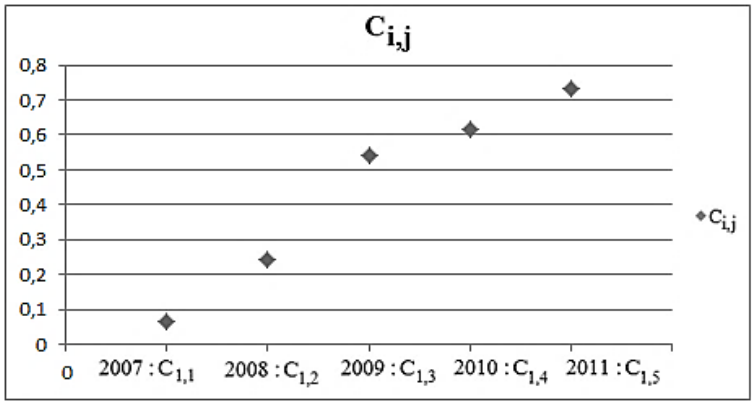


Figure 6.3 Results of performance over years

The data regarding the specific types of solid waste are given in details by CCI Turkey reports (see Table 6.6). Hence, the analysis due to solid waste can be carried due to types of solid waste including the data regarding paper/carton, glass, plastic, metal and the other types of solid waste due to their absolute mass over years.

Table 6.6 Total mass of specific solid wastes per year

	Paper/ Carton	**Glass**	**Plastic**	**Metal**	**Wood**	**Other**
2007	1.253459	1.19721	1.970611	0.846941	1.455044	0.822299
2008	1.335847	1.144864	1.551533	0.566175	1.792685	0.982295
2009	1.335	1.03	1.694	0.493	1.415	1.115
2010	1.444	1.068	1.735	0.522	1.712	0.763

Solid waste disposal prices are used to determine the weights. Unit prices regarding the each type of solid waste are investigated and the weights are calculated in terms of rates cohesively. $Cs_{i,j}$ indicates the j^{th} performance criterion of solid waste used for i^{th} case study.

Figure 6.4 illustrates the performance values of years from 2007 to 2010 according to solid waste mass. It is clearly seen from graph that performance values are

improved for each year except small decrease in 2010. It can be interpreted that, although the wood and other waste amounts are increase, the improvements are observed from 2007 to 2008. Between 2008 and 2009 there was reduction in amounts of each type of wastes.

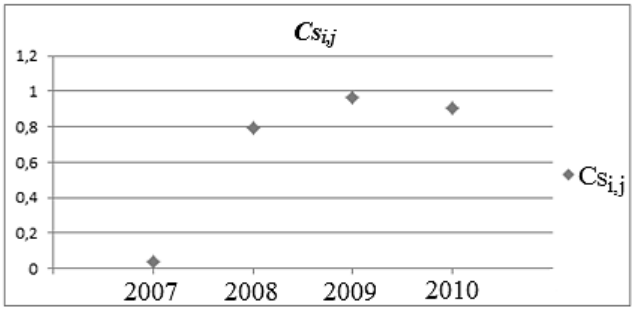


Figure 6.4 Performance values based on solid waste over years

Data for shipping emissions is also provided in details and make possible to analyze the performance of CCI Turkey based on the green gas resulted from the shipping activities per produced liter of beverage.

Table 6.7 represents the yearly amounts of carbon dioxide (CO_2), nitrogen oxide compounds (NOx), suspended particulate matter (PM) and hydrocarbon compounds (HC) per production amount in liter. Weights are determined according the internationally designated tolerance limits. $Ce_{i,j}$ indicates the j^{th} performance criterion of total emission used for i^{th} case study. Figure 6.5 represents that performance criteria of emission values are decreased for each type of gases over years except the small increase in 2011 in comparison with 2010.

Table 6.7 Total emission values for specific types of contaminative per year

	CO_2 g/L	**NOx g/L**	**PM g/L**	**HC g/L**
2007	102.69	1.6735	0.06465	0.0683
2008	85.3	1.39015	0.05372	0.05686
2009	13.64	0.22178	0.00857	0.00912
2010	11.71	0.19057	0.00736	0.00783
2011	15.3	0.24917	0.00963	0.01021

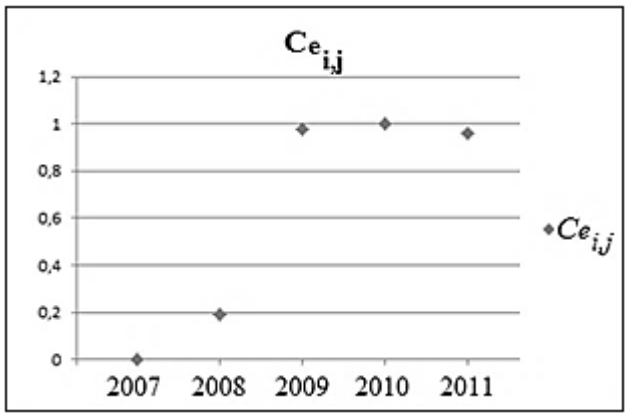


Figure 6.5 Performance values of specific type of emission for each year

6.2 Implementation of TOPSIS Method to CCI Factories in Turkey

This part of study includes detailed analysis for sustainability of CCI-Turkey along six factories: Ankara, Çorlu, Mahmudiye, Mersin, Izmir and Bursa.

First study is conducted in order to compare factories due to specific types of solid waste. Since detailed data for solid waste regarding specific types is provided only for 2007 (see Table 6.8) and 2008 (see Table 6.9), TOPSIS method is applied for these time periods separately. Figure 6.6 contains the radar graph of solid waste mass recorded in 2007 and 2008.

Table 6.8 Total solid waste (1000 tonnes) for specific types in 2007

	Paper/Carton	**Glass**	**Plastic**	**Metal**	**Wood**	**Others**
Ankara	0.12931	0.28686	0.340341	0.06182	0.588794	0.04598
Çorlu	0.61053	0.17359	0.709882	0.07291	0.16722	0.203204
Mahmudiye	0.056324	0.1628	0.38416	0.056	0.00397	0.014266
Mersin	0.20386	0.15206	0.187826	0.1407	0.21345	0.188238
Izmir	0.110992	0.2757	0.170124	0.006541	0.24736	0.102689
Bursa	0.142443	0.309	0.178278	0.50897	0.23425	0.267922

Table 6.9 Total solid waste (1000 tonnes) for specific types in 2008

	Paper/Carton	Glass	Plastic	Metal	Wood	Others
Ankara	0.143079	0.22104	0.259537	0.050526	0.740893	0.07004
Çorlu	0.45794	0.312394	0.439946	0.082097	0.244414	0.22928
Mahmudiye	0.169234	0.2437	0.130662	0.007437	0.17578	0.037289
Mersin	0.17739	0.17494	0.207221	0.167581	0.241438	0.159917
Izmir	0.126279	0.33934	0.232967	0.036394	0.1453	0.114596
Bursa	0.261925	0.09715	0.2812	0.22214	0.24486	0,371173

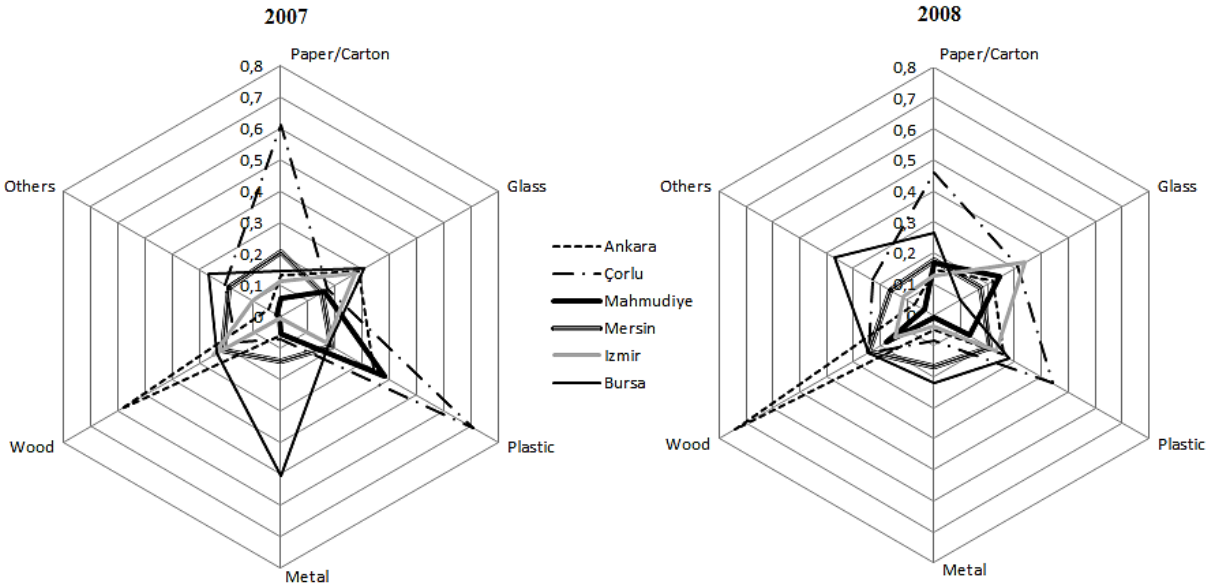


Figure 6.6 Radar graphs indicating specific types of solid waste from six factories for 2007 and 2008

Weights are determined based on unit price of scraps for each type of material. Table 6.10 and 6.11 indicates each factory's the performance results which are illustrated in Figure 6.7. $Cs^{k}_{i,j}$ indicates the j^{th} performance criterion of solid waste in year k used for i^{th} case study.

Table 6.10 Results of performance 2007

Factory	$Cs^{7}_{2,j}$	**Result**	**Factory**	$Cs^{7}_{2,j}$	**Result**
Ankara	$Cs^{7}_{2,1}$	0.869841263	Mersin	$Cs^{7}_{2,4}$	0.735128307
Çorlu	$Cs^{7}_{2,2}$	0.815860663	Izmir	$Cs^{7}_{2,5}$	0.965247252
Mahmudiye	$Cs^{7}_{2,3}$	0.892434383	Bursa	$Cs^{7}_{2,6}$	0.123400233

Table 6.11 Results of performance 2008

Factory	$Cs^{8}_{2,j}$	**Result**	**Factory**	$Cs^{8}_{2,j}$	**Result**
Ankara	$Cs^{8}_{2,1}$	0.785971444	Mersin	$Cs^{8}_{2,4}$	0.276089307
Çorlu	$Cs^{8}_{2,2}$	0.63325341	Izmir	$Cs^{8}_{2,5}$	0.850610133
Mahmudiye	$Cs^{8}_{2,3}$	0.964022169	Bursa	$Cs^{8}_{2,6}$	0.098991577

As a result of comparing the six factories due to total specific types of solid waste mass, it is revealed that the factory in Izmir performed better in 2007. In 2008, the factory in Mahmudiye had the most desired performance value among others.

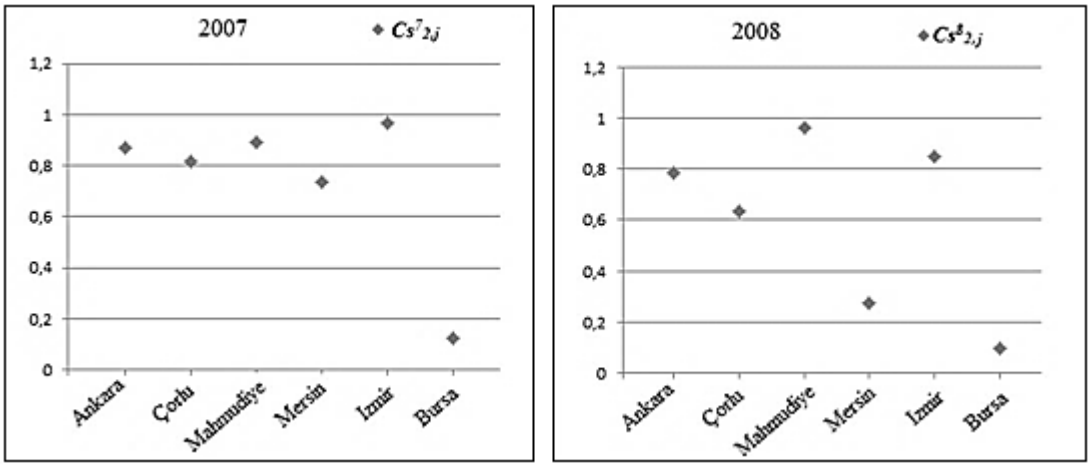


Figure 6.7 Results of performance values in 2007 and 2008

The second study regarding the specified data of CCI Turkey's factories is conducted due to shipping emissions. Data of shipping emission ratio is analyzed for each factory and for 2007 and 2008 separately for the reason that the information about specific types of green gas emission is provided only for 2007 and 2008. TOPSIS method is applied for these time periods separately.

Table 6.12 and 6.13 represent the yearly emissions of carbon dioxide (CO_2), nitrogen oxide compounds (NOx), suspended particulate matter (PM), hydrocarbon compounds (HC), carbon monoxide (CO) and the contaminative gases resulted from consuming diesel combustibles for 2007 and 2008 respectively.

Table 6.12Emission ratio (g/L) for factories' shipping activities in 2007

	CO_2 g/L	NOx g/L	PM g/L	HC g/L	CO g/L	Diesel L/KL
Ankara	18.68	0.30439	0.01176	0.01245	0.04151	6.92
Çorlu	9.28	0.1512	0,00584	0.00619	0.02062	3.44
Mahmudiye	14.64	0.23862	0.00922	0.0096	0.03254	5.42
Mersin	22.37	0.36454	0.01408	0.01491	0.04971	8.29
İzmir	16.61	0.27066	0.01046	0.01107	0.03691	6.15
Bursa	21.11	0.34409	0.01329	0.01408	0.04692	7.82

Table 6.13Emission ratio (g/L) for factories' shipping activities in 2008

	CO_2 g/L	NOx g/L	PM g/L	HC g/L	CO g/L	Diesel L/KL
Ankara	20.31	0.331	0.01279	0.01354	0.04514	7.55
Çorlu	4.91	0.07997	0.00309	0.00327	0.01091	1.82
Mahmudiye	14.55	0. 23713	0.00916	0.0097	0.03234	5.39
Mersin	8.82	0.14381	0.00556	0.00588	10.0961	3.28
İzmir	16.56	0,26988	0.01043	0.01104	0.0368	6.15
Bursa	20.15	0.32836	0.01269	0.01343	0.04478	7.46

Weights are determined based on tolerance limit values of emission for each contaminative gas. Tolerance limits are determined according to international standards. Due to environmental effects of these gases, the criticality plays the main role while determining weights for TOPSIS method. Table 6.14 and 6.15 represents the performance results of each factory for the years 2007 and 2008 respectively. $Ce^k_{i,j}$ indicates the j^{th} performance criterion of total emission in year k used for i^{th} case study.

Table 6.14 Performance results for 2007

Factory	$Ce^7_{2,j}$	**Results**	**Factory**	$Ce^7_{2,j}$	**Results**
Ankara	$Ce^7_{2,1}$	0.312785	Mersin	$Ce^7_{2,4}$	0.189947
Çorlu	$Ce^7_{2,2}$	0.810053	İzmir	$Ce^7_{2,5}$	0.446241
Mahmudiye	$Ce^7_{2,3}$	0.583057	Bursa	$Ce^7_{2,6}$	0.204431

Table 6.15 Performance results for 2008

Factory	$Ce^{8}_{2,j}$	**Results**	**Factory**	$Ce^{8}_{2,j}$	**Results**
Ankara	$Ce^{8}_{2,1}$	0.485768	Mersin	$Ce^{8}_{2,4}$	0.436338
Çorlu	$Ce^{8}_{2,2}$	0.843596	İzmir	$Ce^{8}_{2,5}$	0.559019
Mahmudiye	$Ce^{8}_{2,3}$	0.611836	Bursa	$Ce^{8}_{2,6}$	0.488145

Figure 6.8 illustrates the factories' performance results in 2007 and 2008. It seen from the graph that factories showed similar trends with slight changes on values of performance results comparing 2007 and 2008. It can be also seen that factories in Mersin and Bursa records higher performances with respect to previous year.

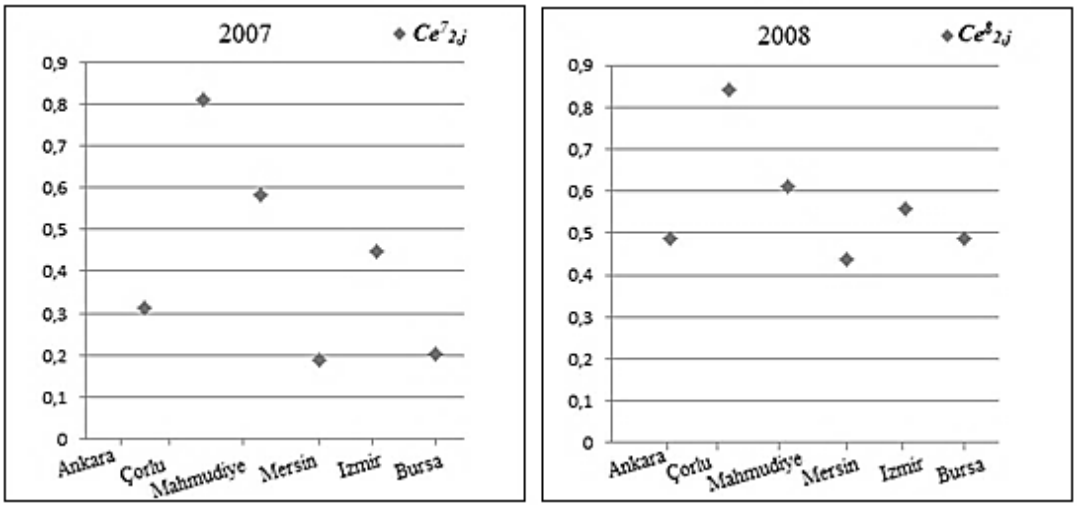


Figure 6.8 Performance values for shipping emission 2007 and 2008

The last study regarding factories in CCI Turkey is developed with 2008's data due to performance indicators from Section 6.1 which are water used per produced liter, solid waste ratio, shipping emission ratio and combustible use ratio for shipping (Table 6.16). Considering the permanency of information, data provided for year 2008 is used in order to compare factories (see Table 6.17).

Table 6.16 Indicators and their expressions

$I_{1,1}$	**Water use ratio (L/L)**	Water used per produced amount of liter
$I_{1,7}$	**Solid waste ratio (g/L)**	Solid waste per liter produced
$I_{1,11}$	**Total shipping emission ratio (g/L)**	Emission per produced liter
$I_{1,12}$	**Combustible use ratio for shipping (L/KL)**	Combustible used/Produced amount of liter

Weights determined for TOPSIS application CCI Turkey in general are also adopted for related indicators. Results are shown in Table 6.18**.** $C^{k}_{i,j}$ indicates the j^{th} performance criterion in year k used for i^{th} case study.

Table 6.17 Data obtained based on indicators

	$I_{1,1}$	$I_{1,7}$	$I_{1,11}$	$I_{1,12}$
Ankara	1.086405409	2.855035046	28.26247	9.6
Çorlu	1.519928203	3.631119043	6.82724	1.91
Mahmudiye	4.665263317	8.053514501	20.22833	5.31
Mersin	1.442534736	2.982582679	22.35135	8.65
İzmir	1.944760042	3.709012208	23.03815	7.58
Bursa	1.829078989	3.83679613	28.00926	6.39

Table 6.18 Performance results for six factories

Factory	$C^{8}_{2,j}$	**Results**	**Factory**	$C^{8}_{2,j}$	**Results**
Ankara	$C^{8}_{2,1}$	0.556977	Mersin	$C^{8}_{2,4}$	0.575928
Çorlu	$C^{8}_{2,2}$	0.901849	İzmir	$C^{8}_{2,5}$	0.561134
Mahmudiye	$C^{8}_{2,3}$	0.282820	Bursa	$C^{8}_{2,6}$	0.598745

It is clearly seen from the Figure 6.9 that the factory in Çorlu performed apparently better at 2008 amongst other factories. The study also reveals that the factory in Mahmudiye has the lowest value along the others. Remaining factories in Ankara, Mersin, Izmir and Bursa shows similar performances in 2008 with slight changes.

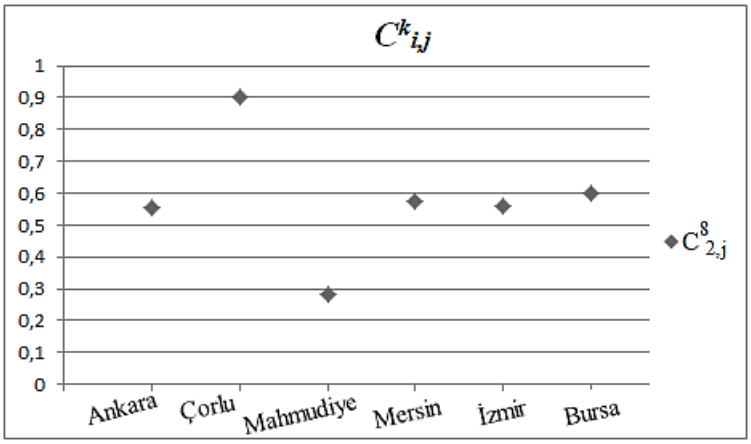


Figure 6.9 Performance criterion of six factories

6.3 Implementation of TOPSIS Method to CCI Kazakhstan over Years

Kazakhstan is one of the CCI countries with 1 plant in Almaty and 2 warehouses in Astana and Shymkent. Coca Cola Almaty Bottlers LLP (CCAB) was established in 1994 and responsible to produce, sell and distribute The Coca Cola Company branded beverages. CCAB serves to population around 16 million. Further information can be found at http://www.cci.com.tr/tr

Table 6.19 Data regarding CCAB over years

	Water use ratio (L/L)	**Energy use ratio (MJ/L)**	**Solid waste ratio (g/L)**	**Recycling ratio (%)**	**CO_2 Emisions ratio (g/L)**
2005	2.1	0.22	4.3	94.4	78.67
2006	2.1	0.18	4.24	94.67	**76**
2007	1.9	0.24	4.23	96.21	114
2008	2.3	0.52	4.3	59	124
2009	1.86	0.33	3.39	**85**	45.83
2010	1.75	0.31	2.04	85.96	45.15
2011	1.7	0.333	2.69	85.34	49.46

All relevant data is derived from CCI reports (see Table 6.19 and 6.20). Since data of recycling in 2009 and CO_2 emission ratio in 2006 is not available in reports,

average of regarding data set is used in application of TOPSIS considering the consistency of implementation.

Table 6.20 Shipping emission ratio of CCAB for specific types of contaminative

	CO_2 g/L	**NOx mg/L**	**PM mg/L**	**HC mg/L**	**CO mg/L**	**Diesel L/KL**
2007	5.01	803.4	3.23	32.9	10.9	0.018
2008	15.8	253.4	9.8	10.4	34.5	0.005
2009	4.92	80.16	3.1	3.28		
2010	3.2	52.1	2.01	2.13		
2011	7.05	114.81	4.44	4.7		

While analyzing the emissions resulted from shipping activities, carbon monoxide and gases from diesel combustible are not included because of the absence of data for years 2009-2011 relatively.

Table 6.21 Performance values of CCAB due to indicators over years

Year	$C_{i,j}$
2005: $C_{3,1}$	0.7383682
2006: $C_{3,2}$	0.776215
2007: $C_{3,3}$	0.6994959
2008: $C_{3,4}$	0
2009: $C_{3,5}$	0.590636
2010: $C_{3,6}$	0.6662403
2011: $C_{3,7}$	0.6055345

Indicators representing the water use ratio, energy use ratio, solid waste ratio, recycling percentage and carbon dioxide emissions are adopted from previous applications. Due to considerations regarding the consistency the weights used in previous applications are adopted. Table 6.21 represents the performance values over years.

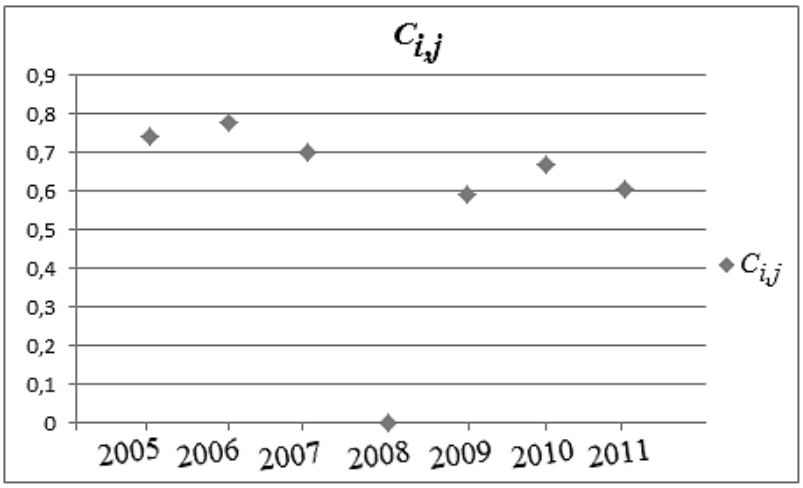


Figure 6.10 Performance values for CCAB over years

Figure 6.10 illustrates the performance results due to sustainability indicators over years. Performance value of year 2008 draws attentions with $C_i = 0$ indicating the absolute closeness of the corresponding year to the negative ideal solution. It is difficult to make an inference by reviewing the table representing information of CCAB but the data regarding the 2008 apparently signals this outcome with its relatively undesirable values

Emission ratio due to shipping activities in Kazakhstan is analyzed with the same sense of previous analyses. Table 6.22 shows performance results based on emission ratio recorded for each year. $Ce_{i,j}$ indicates the j^{th} performance criterion of shipping emission used for i^{th} case study. As a result of the TOPSIS method, the lowest performance is displayed at 2010. A fluctuating trend is observed over years for shipping emission ratio (see Figure 6.11)

Table 6.22 Performance values of CCAB over years for shipping emissions

Year	$Ce_{3,j}$
2007: $Ce_{3,1}$	0.686244867
2008: $Ce_{3,2}$	0.507003438
2009: $Ce_{3,3}$	0.799715484
2010: $Ce_{3,4}$	0.285490098
2011: $Ce_{3,5}$	0.496339105

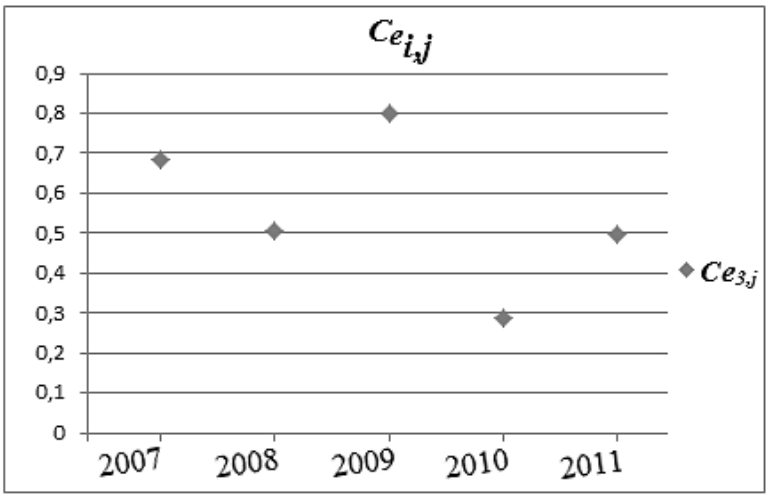


Figure 6.11 Performance values of CCAB due to shipping emissions over years

6.4 Implementation of TOPSIS Method to CCI Jordan over Years

With the one operational plant included a sales warehouse and three warehouses, the Coca-Cola Bottling Company of Jordan (CCBCJ) serves a population around 7 million. CCBCJ was established in 1993 and since then the company has produced, sell and distributed Coca-Cola branded beverages. Further information can be founded at http://www.cci.com.tr/tr

Table 6.23 Data of CCBCJ over years

	Water use ratio (L/L)	**Energy use ratio (MJ/L)**	**Solid waste ratio (g/L)**	**Recycling ratio (%)**	**CO_2 Emisions ratio (g/L)**
2005	3.78	1.69	28.092	76	161.57
2006	3.44	1.12	15.723	81.6	50
2007	2.38	0.62	10.261	76.95	22
2008	1.89	0.57	6.959	72.87	17
2009	1.82	0.52	7.97	79	64.06
2010	1.97	0.51	15.95	86.4	72.44
2011	2	0.455	11.19	88.9	56.03

Similarly to evaluation of production activities with respect to designated indicators from previous applications in CCI Turkey and Kazakhstan, data recorded from

manufacturing activities in Jordan and emission ratio regarding specific types of greenhouse gases from shipping activities are evaluated separately (see Table 6.23 and 6.24).

Table 6.24 Shipping emission ratio of CCBCJ for specific types of contaminative

	CO2 g/L	**NOx mg/L**	**PM mg/L**	**HC mg/L**	**CO mg/L**	**Diesel L/KL**
2007	22.24	362.49	14.01	14.83	49.43	8.24
2008	15.2	247.77	9.57	10.14	33.79	5.63
2009	21.59	351.89	13.6	14.4		
2010	58.48	598.58	24.18	61.91		
2011	21.09	342.69	13.24	14.02		

Considering the consistency of analyses, weights determined for previous TOPSIS applications are used in evaluation of CCBCJ for manufacturing data and also for shipping emissions. Table 6.25 contains performance values resulted from application on indicators due to the years.

Table 6.25 Performance values of CCBCJ due to indicators over years

Year	$C_{i,j}$
2005: $C_{1,1}$	0.015428731
2006: $C_{1,2}$	0.465661297
2007: $C_{1,3}$	0.830652407
2008: $C_{1,4}$	0.894428398
2009: $C_{1,5}$	0.882052451
2010: $C_{1,6}$	0.824139004
2011: $C_{1,7}$	0.892355747

TOPSIS method reveals that the CCBCJ improves its performance over years. It can be interpreted from graph regarding performance results; the best performance value belongs to the year of 2008 and with slight decrease in 2011 (see Figure 6.12).

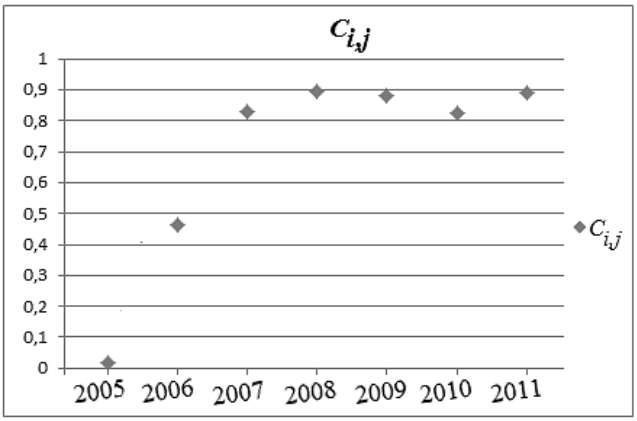


Figure 6.12 Performance values for CCBCJ over years

Results of TOPSIS method applied on shipping emission are expressed in Table 6.26. Carbon monoxide and gases resulted from consuming the diesel combustibles are not included the analysis of shipping emissions for Jordan because the reports prepared for CCBCJ not provide data of emissions due to those contaminative gases between 2009 and 2011. $Ce_{i,j}$ indicates the j^{th} performance criterion of shipping emission used for i^{th} case study.

Table 6.26 Performance values of CCBCJ over years for shipping emissions

Years	$\boldsymbol{Ce_{i,j}}$
2007: $\boldsymbol{Ce_{4,1}}$	0,8263663
2008: $\boldsymbol{Ce_{4,2}}$	1
2009: $\boldsymbol{Ce_{4,3}}$	0,8419533
2010: $\boldsymbol{Ce_{4,4}}$	0
2011: $\boldsymbol{Ce_{4,5}}$	0,85520318

It is revealed that the year 2008 absolutely close to the positive ideal solution while the year 2010 is absolutely close to the negative ideal solution. Beside those years performance values the CCBCJ performs similarly at 2007, 2009 and 2011. Figure 6.13 presents the change of performance results over years from 2007 to 2011.

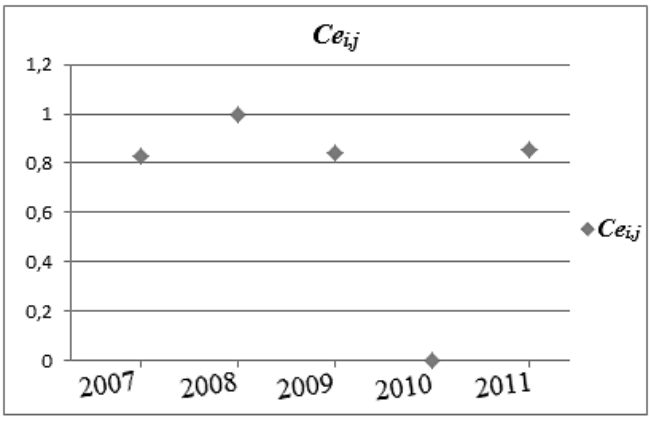


Figure 6.13 Performance values for CCBCJ due to shipping emissions over years

6.5 Implementation of TOPSIS Method to Compare CCI Turkey, Kazakhstan, Jordan and Azerbaijan

Azerbaijan is one of the CCI countries and included to the analysis where comparing the Turkey, Kazakhstan and Jordan which are separately evaluated at the previous sections. Data regarding these four countries can be reviewed from Table 6.2.

Table 6.27 Data from 2011 provided by CCI reports for four countries

	Turkey	**Jordan**	**Kazakhstan**	**Azerbaijan**
Water use ratio(L/L)	1.42	2	1.7	1.74
Water use amount (m^3)	3850537	137847	510591	306059
Energy use ratio (MJ/L)	0.255	0.455	0.333	0,222
Total energy use from primary resources (million 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	9405144	915899	1231340	929920
Total number of employees	2820	368	599	269

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 representing in Table 6.28. The year of 2011 is chosen in order to apply TOPSIS method because the data is provided completely for those countries where the consistent analysis is possible considering the designated indicators. Addition to existing product indicators, a new indicator is included to the analysis. Differently from the previous analyses, new indicator appertains to the group of social indicators. These indicator is specified as $I_{5,1}$ whose indicated meaning is shown in Table 6.28 with the other indicators.

Likewise previous analyses, shipping emissions are also investigated separately from manufacturing activities. Data regarding shipping emission is shown in Table 6.29.

Table 6.28 Indicators and their expressions

$I_{1,1}$	**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 emisson 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

Table 6.29 Shipping emission ratio for specific types of contaminative at 2011

	CO_2 g/L	NOx g/L	PM g/L	HC g/L
Turkey	15.3	0.24917	0.00963	0.0102
Jordan	21.09	0.34269	0.01324	0.014
Kazakhstan	7.05	0.11481	0.00444	0.0047
Azerbaijan	13.37	0.14319	0.00601	0.0122

Evaluation matrix (see Table 6.30) is built due to the indicators and steps of TOPSIS method are applied. Likewise previous analyses the same weights are used where possible. Indicators indicated the values of absolutes mass are assigned relatively small weights since the records related those value can be change the capacity of the plant. As a result of the TOPSIS method, performance values are obtained as stated in Table 6.31.

Table 6.30 Evaluation matrix for comparison of the four countries

	$I_{1,1}$	$I_{1,3}$	$I_{1,4}$	$I_{1,5}$	$I_{1,7}$	$I_{1,9}$	$I_{1,10}$	$I_{1,11}$	$I_{1,12}$	$I_{5,1}$
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

It is seen from the Figure 6.14 clearly that Azerbaijan had better performance at 2011 amongst other countries. Turkey and Jordan share almost the same scores despite the differences of data indicated from Table 6.27.

Table 6.31 Performance values of countries

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

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.

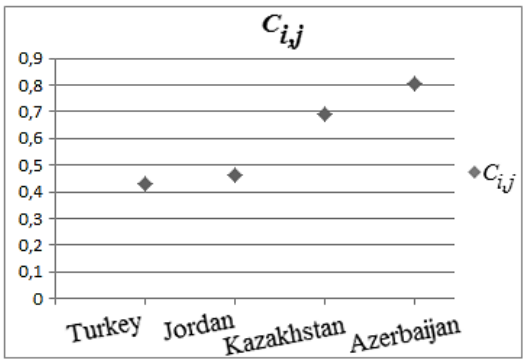


Figure 6.14Performance values for Turkey, Jordan, Kazakhstan and Azerbaijan at 2011

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 6.15 illustrates the radar graph which provides better understanding for this statement.

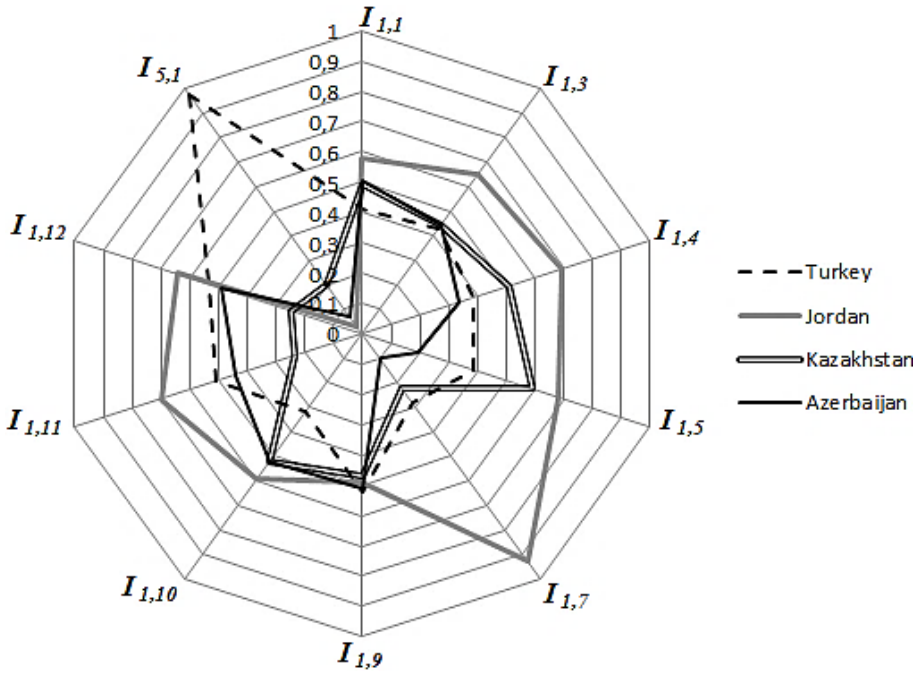


Figure 6.15 Radar graph representation of evaluation matrix

Emissions due to shipping activities also compared for those countries. It can be seen from the results that Jordan and Kazakhstan performs at the levels of negative and positive ideal solutions respectively (see Table 6.32). $Ce_{i,j}$ indicates the j^{th} performance criterion of shipping emission used for i^{th} case study.

Table 6.32 Performance values of countries over years for shipping emissions

Countries	$Ce_{i,j}$	**Countries**	$Ce_{i,j}$
Turkey: $Ce_{1,1}$	0.41056	**Kazakhstan:**$Ce_{1,3}$	1
Jordan: $Ce_{1,2}$	0	**Azerbaijan:** $Ce_{1,4}$	0.57911

Figure 6.16 represents the performance results of four countries. Descending order of the size of the countries in terms of surface area is Kazakhstan, Turkey, Jordan and Azerbaijan. It might be excepted that the largest country performs the best result where the smallest one shows the worst performance. Hovewer, shipping emission is anayzed base on amounts of greenhouse gases per produced liter of beverage considering the weights. Since weights are determined according to tolerance limits related to potential damages of environment, the results are meaningful in terms of critical gase emissions.

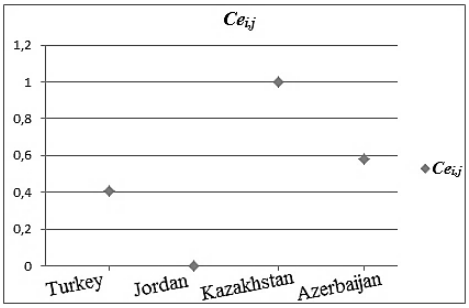


Figure 6.16 Performance values of countries over years for shipping emissions

6.6 Comparison of CCI Turkey and Countries Contained by Coca-Cola System

The Coca-Cola system (CCS) refers the worldwide manufacturers and more than 250 bottling partners spread the five main areas categorized as Eurasia & Africa, Europe, Latin America, North America and Pacific. Reports regarding countries from

those areas are examined by region-by-region and data which can be used in the comparison of Turkey and CCS. The general reports regarding the CCS reports are also examined. Since the data from those reports are not provided properly, it is decided to use the gathered from regional reports. In order to procure the consistency, data from the reports of 2011 are considered.

Unfortunately not all the CCS countries are included to the application. Data is gathered mostly from the European countries such as Belgium, Netherlands, Switzerland; Eurasia-Africa countries represented by Coca-Cola Hellenic which includes 77 bottling plants across the 28 countries and Latin America countries represented by Coca-Cola FEMSA consists of Argentina, Brazil, Colombia, Costa Rica, Guatemala, Mexico, Nicaragua, Panama and Venezuela. However, data combined from reports of these countries and mentioned as countries contained by Coca-Cola system (CCCS).

Because of the difficulty to obtain information in numbers that enables indicators to be applicable, only water use ratio, energy use ratio, direct CO_2 emission ratio, product waste ratio and recycling ratio are used in analysis. Indicators are calculated as it seen from Table 6.33.

Table 6.33Combined data of CCS countries and Turkey

	Water Use Ratio (L/L)	**Energy Use Ratio (MJ/L)**	**CO_2 Emsission Ratio (g/L)**	**Product Waste Ratio (g/L)**	**Recycling Ratio (%)**
Turkey	1.42	0.255	30.1	3.38	94.95
CCCS	1.776	1.306	17.01	6.976	91.2

Results can be predictable as a consequence of comparing two alternatives. Since there is no meaning to apply TOPSIS method for comparing only two alternatives, data gathered from Table 6.33 is expressed by radar graph (see Figure 6.17). It is possible to observe and interpret the changes over data. It draws attention that Turkey has relatively good data considering the ideal solution where recycling ratio ($I_{1,9}$)

desired to be at the highest level when the other indicators are expected to be as lower as possible.

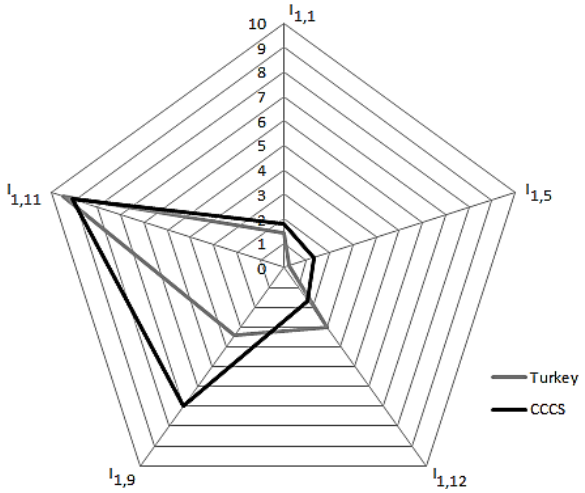


Figure 6.17 Radar graph representation of Turkey and CCCS on indicators

It can be derived from Table 6.33 that data of CO_2 emission ratio is the only indicator where CCCS had better results than Turkey. It could be a cause of the strong regulations and enforcements adopted by countries included Coca-Cola system worldwide. However, combining data of numbers of country might lead the data for CCCS to be relatively higher and it is more reliable to compare countries separately or regionally.

It can be derived from Table 6.33 that data of CO_2 emission ratio is the only indicator where CCCS had better results than Turkey. It could be a cause of the strong regulations and enforcements adopted by countries included Coca-Cola system worldwide. However, combining data of numbers of countries might lead the data for CCCS to be relatively higher. Hence, it is more reliable to compare countries separately or regionally. When there is apparent observations can be made along data set, it is not necessary to use a multi-criteria decision method. Yet, TOPSIS can provide a broad analysis for comparisons in which priority of the criterion plays important role.

CHAPTER SEVEN
CONCLUSION

Under the lead of technological improvements, development efforts increased rapidly. Due to the manufacturing activities which are the natural results of industrial growth, our world suffers from environmental problems leading by depleted natural resources and pollution. Technological and industrial improvements also lead globalization resulted for countries to be affected by each other's impacts of environment. The world has become global and environmental problems due to manufacturing activities have become global problems. The concept of using resources without consuming them and manufacturing without harming the environment as much as possible causes the term sustainability and sustainable development to be born. Beside economic pressure and consumption of resources, manufacturers have been faced with increasing costs and creating adding value for customers. As a result of these circumstances manufacturers adopts 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 their impacts to environment provides manufacturers to realize the importance of assessment.

Since several researchers gives utmost importance to design and develop indicators indicates environmental impacts of manufacturing activities there has been a big gap in literature in terms of application of assessment methods by using sustainability indicators. This thesis contributes to literature by concerning performance evaluations by using indicators. This thesis focuses on the application of TOPSIS method that provides the evaluation of sustainability performance of manufacturing systems considering various sustainability indicators simultaneously.

Two problems are generated as examples where TOPSIS method is explained. Assessment of sustainability with production indicators is introduced in these examples in order to clarify the method and provide broader understanding for real-life cases addressed at the application phase of this thesis.

At the application phase of this thesis, relevant data is collected and examined from the annual social responsibility and sustainability reports of Coca-Cola Company. TOPSIS method is applied by using data of Coca-Cola Company. Several applications are practiced. First case study is assessment of CCI Turkey over years based on total data across the country. Total of twelve indicators are designated in order to use for implementation of TOPSIS. Additionally, solid waste and shipping emission values are analyzed in detail. The second case contains comparison of the factories in Turkey. Factories are assessed according to specific types of solid waste and shipping emission in details for years 2007 and 2008 separately. Moreover, the assessment according to general data provided from production activity is practiced for 2008. In the third case study, Kazakhstan is investigated based on total data all across the country over years. Furthermore, shipping emission for specific types of contaminant gases is assessed over years. The fourth study is developed for Jordan with the same sense adopted in case study four. The fifth case includes comparison of Turkey, Kazakhstan and Jordan and Azerbaijan based on data gathered from production activities across these countries in 2011. Beside the designated indicators in the first case study, one more indicator is developed for this case. As an addition, these countries are compared due to shipping emissions in 2011. In the last case study CCI Turkey and Coca-Cola system is compared by using radar graph. Since these two alternatives can be distinguished apparently, radar graph is a proper tool enables us to assess CCI Turkey and Coca-Cola system.

These case studies focused on usage of sustainable manufacturing indicators for performance evaluation and concerned the application of the TOPSIS method which provides advantages of sufficiency and simplicity while identifying the most suitable alternative quickly in case of the conflicting criterion. Some of the assessment methods are not suitable to use when it comes to assessing sustainability for manufacturing. Also, some of these methods require expertise and some of them cannot manage with trade-offs between indicators. Case studies reveal that it is easy to use TOPSIS. TOPSIS method has several advantages such as the application practicability and simplicity. The method enables decision maker to identify the suitable alternative quickly.

Future studies can be formed in the manner that concerns to reflect the vagueness concept of sustainability, fuzzy TOPSIS could be applied on sustainability indicators and to analyze the outputs of the fuzzy TOPSIS. Since there are limited studies related to the subject, it is possible to investigate different sectors. Additionally, different decision making methods can be adopted in order to evaluate sustainability performance considering multi criteria structure of the topic.

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