Available online at www.alphanumericjournal.com

alphanumeric journal

The Journal of Operations Research, Statistics, Econometrics and Management Information Systems

Volume 8, Issue 1, 2020

Received: July 10, 2019
Accepted: May 31, 2020
Published Online: June 30, 2020

AJ ID: 2020.08.01.OR.05
DOI: 10.17093/alphanumeric.590216
Research Article

Sustainable Warehousing: Selecting The Best Warehouse for Solar Transformation

Rasih Boztepe, Ph.D.

Reysaş Transportation and Logistics Co., rasihb@gmail.com

Onur Çetin, Ph.D. *

Assist. Prof. Department of Business Administration, Faculty of Economic and Administrative Sciences, Trakya University, Edirne, Turkey, onurcetin@trakya.edu.tr

* Trakya Üniversitesi İktisadi ve İdari Bilimler Fakültesi İşletme Bölümü, Balkan Yerleşkesi, 22030 Edirne Türkiye

ABSTRACT

Environmental sustainability has been gaining importance not only in manufacturing but also in logistics and supply chain. Logistics sector has a significant responsibility in global energy consumption. The effect of warehouse on carbon emission demonstrates its importance of warehousing regarding sustainability. One way of developing sustainable warehouses is using renewable energy sources. In a solar warehouse; which is a new example of sustainable warehousing, roof of the warehouse is covered with solar panels so, both energy costs and carbon emission are reduced. Warehouses have been turning into solar warehouse in recent years. While there is a substantial literature regarding sustainable supply chain, literature regarding sustainable warehousing is limited. In order to contribute this gap in the literature the problem conducted here is selecting the best warehouse to be turned into a solar warehouse. In other words, the aim of the research is ranking the alternative warehouses according to solar facility location criteria in order to find best alternative. In this context first the alternative warehouses that can be turned into solar warehouse are determined then, the criteria which will be used in evaluation process is obtained from previous research. TOPSIS method is used to rank the alternative warehouses. The evaluation of alternatives according to solar facility location criteria is obtained from expert opinions and secondary data. The ranking obtained with TOPSIS method is compared with another ranking based on payback period of investment. The differences observed between two rankings is discussed and compared.

Keywords: Sustainable Warehousing, Solar Warehouse, Facility Location, TOPSIS

1. Introduction

Sustainability is one of the most crucial concepts in business world for the last decades. Sustainable Supply Chain Management (SSCM) focuses not only economic goals of the supply chainbut also environmental and social goals by coordinating processess in order to achieve long term performance (Carter and Rogers, 2008: 368). A similar concept to SSCM is Green Supply Chain Management (GSCM). GSCM can be defined as considering environmental factors in SCM. In the literature several aspects of SSCM and GSCM is analyzed from different aspects. From a supplier viewpoint sustainable monitoring and encouraging activities of the suppliers Ageron et al. (2012), selecting green suppliers Kannan et al. (2014) and sustainable environmental purchasing in GSCM (Zsidisin and Siferd; 2001) may be considered as important activities. Cooperation in new green product development, green process development, using green technologies, using pollution preventive technology, reducing waste in energy usage are activities of green partnership (Vachon and Klassen, 2006). From a reverse logistics viewpoint GSCM includes recycling and remanufacturing (Zhu ve Sarkis, 2004).

Warehouses has an important role in environmental sustainability as well. Res et al. (2017) states that warehousing is responsible for huge amunt of CO2e. While warehousing is one of the most important activities in supply chain, most of the warehousing companies have little effort for environmental issues (Tan et al. 2009). Ciliberti et al. (2007) reported SSCM practices of Italian companies and found that 56% of the companies practice environmental purchasing, 20% of the companies practice sustainable transportation, 17% practice reverse logistics, 6% for sustainable packaging and only 1% practice sustainable warehousing. As well as the practical applications, academic research on sustainable warehousing is limited when compared with other supply chain activities.

This research focuses on the concept of sustainable warehousing. The problem is to determine the best warehouse to be turned in to a solar one among six alternative warehouses. Fırst the concept of sustainable warehousing is mentioned. In the next part of the study the methods of facility location selection is underlined as the problem dealed is a kind of facility location selection problem. The method used is analyzed and findigs is discussed.

2. Sustainable Warehousing

Warehousing can be defined as the storage of materials (packaging, finished goods and raw materials) at different stages of the supply chain (Chopra and Meindl, 2016). While in the past storage activities were defined as the activities of keeping stocks or keeping them safe, storage activities today figure far beyond that. In a way, storage might be seen as an unnecessary and compulsory activity that does not create value, but on the other hand, contemporary storage activities involve many implementations that actually create value. Disassembly, consolidation, delaying, cross-shipment, final assembly and packaging activities can be given as examples of these implementations (Bowersox, 2002). The changes in the activities carried out in warehouses can be listed as follows (Frazelle, 2001);

- More transactions are performed, and the transactions have now less product range.

- Storing and handling more products.
- Increased customer-oriented customization of products and services.
- Offering more of value-added services in warehouses.
- Management of larger volumes of product return.
- A larger amount of international orders.
- On the other hand, despite all these increases, there is less time to complete orders and less fault tolerance.

When it comes to sustainabile warehouse, it can be said that sustainability in warehouses has several aspects. Amjed et al. (2013) determined constructs of sustainable warehousing as warehouse facility design, warehouse layout, inventory management, warehouse staff, warehouse operations, onsite facilities, warehouse management system and mechanical handling equipment. Sustainability elements for facility design are reported as using renewable energy sources, daylight use, artificial lighting scheme, temperature control, noise pollution and biodiversity.

Ries et al. (2017) abstracted the research on sustainable warehousing. The research on sustainable warehousing focused on reducing energy usage and emissions in warehouse activities (Ala-Harja and Helo 2014; Dadhich et al. 2015; Dekker, Bloemhof, and Mallidis 2012; Dhooma and Baker 2012; Fekete et al. 2014; Makris, Makri, and Provatidis 2006), sustainable automated warehousing (Meneghetti, Borgo, and Monti (2015a); Meneghetti, Dal Borgo, and Monti (2015b); Meneghetti and Monti (2015); Meneghetti and Monti (2014); Meneghetti and Monti (2013); Tappia et al., 2015) and sustainable and green warehousing management (Żuchowski 2015; Tan et al. (2010).

One of the new activities related to sustainable warehouses is the production of electricity with solar panels in the roof of the warehouses. Therefore, carbon emissions of warehouses are reduced and warehouse revenues increase with the sale of electricity energy obtained. The literature on solar warehousing is limited as well. Knez, Bajor and Seme (2011) described the solar warehouse concept and focused on the important criteria regarding solar warehouse. Boztepe (2018) studied facility location slecetion using ANP (Analytic Network Process) with a set of criteria including economical, infrastructure. market, geographic, social environment and and solar warehouse location. Determining which warehouse will be turned into a solar warehouses is a problem of location selection and it has some differences compared to traditional location selection problems.

3. Facility Location for Sustainable Warehouse

Businesses want to choose the most appropriate facility location for their long-term goals. Facility location selection is closely related to other activities such as production control, material handling and organization of the site, and especially the production planning activity of the enterprise. Selection of facility or warehouse location is a complex and strategic planning problem where all activities within the logistics network between supply sources and product demand points are designed within the entire logistics system. A bad facility location decision can cause high cost, lack of resources or financial losses. One of the important issues such as process improvement, stock policies, routing or scheduling, which should not be ignored during the examination of a logistics network, the facility location selection decision is a business decision that directly affects balance sheet items (Meade and Sarkis, 1998). Considering the costs such as transportation cost, labor cost, taxes, raw material costs, and real estate costs, which are affected by the facility location decision, it is evaluated that the location selection decision affects 50% of the total operation costs (Heizer et al., 2017).

The facility location selection is made with a long-term planning. For this reason, the selection of location must be made by considering a number of criteria. Factors influencing the selection of the site of establishment can vary by industrial sector and by service sector (Krajewski et al., 2013).

The purpose of the facility location decision may vary depending on the type of business. The aim for the industrial sector is generally to minimize costs. In addition, increasing innovation and creativity may also be a goal. The goal for retailers and service businesses may be maximizing revenue rather than cost minimization. For example, in the decision on location selection for a warehouse, the objective may be a combination of cost and delivery speed criteria (Heizer et al., 2017). One of the criteria in faclity location may be environmental factors or sustainability factors (Uysal ve Tosun, 2014; Raut et al. 2017; Boztepe, 2018; Jha et al. 2018; Foroozesh, 2018).

According to Stevenson (1996), the main process used in the analysis of site of establishment, alternative decision points and evaluation criteria in variables are as follows:

- Determining the criteria affecting location selection
- Determining the weights of the criteria affecting location selection
- Identifying alternative places suitable for criteria affecting location selection
- Evaluation of the suitable alternatives to criteria affecting location selection.

There are many methods used in the facility location decision. In general, these methods can be listed as mathematical methods, statistical methods and multi criteria decision methods (MCDM). Kahraman et al. (2003) presented several fuzzy MCDM methods for facility location. TOPSIS method is also one of the multi criteria decision methods used in logistics for site selection. Demirel et al. (2010) provided a Choquet integral for selection problem of a real warehouse location. Ertuğrul and Karakaşoğlu (2008) used the TOPSIS method in the selection of the site of establishment of the manufacturing company, while Ulukan and Kop (2009) used it in the location selection of the facility for the waste plant. Awasthi et al. (2011); applied the Fuzzy TOPSIS method in the site of establishment selection for a distribution center. Yavuz and Deveci (2014) applied Fuzzy TOPSIS and Fuzzy VIKOR methods in the location selection for a shopping mall. Choudhary and Shankar (2012) carried out a location problem for a thermal power station with Analytic Hierarchy Process (AHP) and TOPSIS methods. After calculating the weights of criteria and alternatives according to the AHS method, the site of establishment alternatives were evaluated according to the Fuzzy TOPSIS method by the general performances and the best place was selected. Sezer et al. (2016) studied warehouse selection for hazardous materials.

While selection of warehouse location is an important strategic matter as it has significant effects on economic, environment and social sustainability (Tan et al., 2009) the literature regarding sustainable warehouse location selection is limited when compared with the literature regarding other sustainable supply chain activities. Some of the literature regarding sustainable facility location is as follows. Uysal and Tosun (2014) conducted sustainable warehouse location selection among six alternatives using Grey Analysis. Raut et al. (2017) studied sustainable warehouse location problem for a chemical facility using AHP method. Boztepe (2018) selected facility location for a solar warehouse. Jha et al. (2018) identified and modelled critical success factors for selection sustainable warehouse for Indian chemical industries. Foroozesh (2018) studied sustainable warehouse location under uncertainity using internal valued fuzzy sets.

4. TOPSIS Method

The steps of the TOPSIS method are described below (Özdemir, 2014).

Step 1: Creation of Decision Matrix (A)

In the rows of the matrix, there are decision points to be ranked according to their superiorities, while in its columns there are evaluation factors to be used in decision making. Matrix A is the starting matrix created by the decision maker. The decision matrix is shown as follows:

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

A_{ij} In the matrix, m gives the number of decision point, while n gives the number of evaluation factor.

Step 2: Creating the Standard Decision Matrix (R)

Obtaining the Standard Decision Matrix is a kind of normalization. Normalized Matrix (R) is calculated with the elements of matrix A, using the formula (1).

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad (1)$$

The matrix R is obtained as follows:

$$R_{ij} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}$$

Step 3: Formation of Weighted Standard Decision Matrix (V)

Firstly, weight values related to evaluation factors (WI) are determined. The sum of (Wi) will be 1.

Then, the elements in each column of the matrix R will be multiplied by the value related to (WI) to generate the matrix V. The matrix V is shown below:

$$V_{ij} = \begin{bmatrix} w_1 r_{11} & w_2 r_{12} & \cdots & w_n r_{1n} \\ w_1 r_{21} & w_2 r_{22} & \cdots & w_n r_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 r_{m1} & w_2 r_{m2} & \cdots & w_n r_{mn} \end{bmatrix}$$

Step 4: Creating Ideal (A^*) and Negative Ideal (A^-) Solutions

The TOPSIS method assumes that each evaluation factor has either a monotonous increasing or a decreasing trend. In order to create the ideal solution set, in the matrix V, the largest value of the weighted evaluation factors, namely the largest column values, are selected. (If the relevant evaluation factor is minimization oriented, the smallest is selected) Finding the ideal solution set is shown in formula (2).

$$A^* = \left\{ (\max_i v_{ij} \,\middle|\, j \in J), (\min_i v_{ij} \,\middle|\, j \in J^{'} \right\} \tag{2}$$

The set to be calculated by this formula can be shown as: $A^* = \{v_1^*, v_2^*, v_3^*, \dots, v_n^*\}$.

The negative ideal solution set, on the other hand, is created by selecting the smallest of the weighted evaluation factors in the matrix V, namely the smallest column values. (If the relevant evaluation factor is maximization oriented, the largest is selected) Finding the negative ideal solution set is shown in formula (3).

$$A^- = \left\{ (\min_i v_{ij} \,\middle|\, j \in J), (\max_i v_{ij} \,\middle|\, j \in J^{'} \right\} \tag{3}$$

can be shown as: $A^* = \{v_1^-, v_2^-, v_3^-, \dots, v_n^-\}$.

In both formulas, *J* shows benefit (maximization), and *J′* shows the value of loss (minimization).

In the formulas shown above; if the criteria are benefit-oriented, they show maximization J in the ideal solution set, and they show minimization J in the negative ideal solution set. Likewise, if the criterion is cost-oriented, it indicates the minimization J in the positive ideal solution set, and the maximization J in the negative ideal solution set.

Both the ideal and the negative ideal solution set consist of the number of evaluation factor, namely the element m.

Step 5: Calculation of Discrimination Measures

In each evaluation factor value related to decision point in the TOPSIS method, Euclidean Distance Approach is used to find deviations from ideal and negative ideal solution set. The deviation values for the decision points obtained here are called the Ideal Discrimination (S_i^*), and Negative Ideal Discrimination Measure. (S_i^-), Calculating both Ideal Discrimination (S_i^*), and Negative Ideal Discrimination measures (S_i^-), are demonstrated in order by the formula (4) and (5).

$$S_i^* = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^*)^2} \tag{4}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \tag{5}$$

The numbers (S_i^*) and (S_i^-), to be calculated here will naturally be same as the number of decision point.

Step 6: Calculation of Relative Proximity to Ideal Solution

When calculating the relative proximity of each decision point to the ideal solution (C_i^*), the ideal and negative ideal discrimination measures are used. The criterion used here is the share of the negative ideal discrimination measure in the total discrimination measure. The calculation of the relative proximity value to the ideal solution is shown in the formula (6).

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{6}$$

Here C_i^*, value is between the range of $0 \leq C_i^* \leq 1$ and $C_i^* = 1$ shows the proximity of related decision point to the ideal solution, while $C_i^* = 0$ shows the proximity of related decision point to the negative ideal solution.

5. Real Life Problem

This study is conducted in a logistics company in Turkey in 2017. The Company has six warehouses alternatives that can be converted into solar warehouses. The problem is determining which warehouse to be converted to a solar one. Each alternative warehouse is located in a different city. The similar problem is studied by Boztepe (2018). Boztepe developed an ANP model for a new solar warehouse facility location selection among five alternative locations using a set of criteria including economical, infrastructure. market, geographic, social environment and solar warehouse location. Having weights of alternatives form ANP results he used TOPSIS method to rank the alternatives. He used only three criteria regarding solar warehouse location. The problem is to determine the best warehouse to be turned in to a solar one among six alternative warehouses. This research aims to make a ranking using only solar warehouse location criteria.

The solar criteria for a solar warehouse location selection were previously determined by Boztepe et al. (2015) with AHP method. The criteria and weights is shown in Table 1. The most important criterion is the radiation value of the region, while the least significant criterion is the self-consumption within the warehouse. The weight of self-consumption is small according to AHP results obtained by literature because Turkey government gives guarantee to buy the electricity produced by the facilities such as warehouses. So even if the warehouse cannot consume all the electricity it produces, it can sell the electricity to the government.

A1. Annual irradiation values of the regions (kwh/m^2)	0,319
A2. Solar annual time (hour/year)	0,199
B1. Shadowiness risk of solar panel in future	0,152
C3. Angle and direction of warehouse for sunshine	0,089
B3. Closeness of warehouse to nearest electricity network	0,072
A3. Seasonality in solar electricity production	0,050
C2. Area of the Roof	0,044
B2. Other Factors that Limit Solar Electricity Production	0,033
A4. Amount of wind in the area	0,028
C1.Self consumption of electricity in Warehouse	0,014

Table 1. Weights of Solar Warehouse Selection Criteria (Boztepe R., Özçakar, N., Çetin, O., 2015).

The criteria in Table 1. is used to rank the warehouses in this research. Ranking of alternatives is conducted by TOPSIS method. In TOPSIS method each alternative is scored according to ten criteria in Table 1.

Two different approaches are used to determine the scores of the alternatives according to the criteria. Secondary data is used for criteria that can be directly obtained. For the criteria that could not be imported directly, expert opinion is used. Two of the experts are two senior managers of the company that own the warehouses. They were managers of the company's earlier projects on solar warehouses. The third expert is the manager of the company that builds solar facilities and converts the roofs into solar roofs by solar panels. All experts are experienced in solar warehousing and have knowledge about alternative six warehouse. The experts were asked to rate the six alternatives according to ten criteria.

The criteria A1 is the annual irradiation values of the regions, and the criteria A2 is the solar annual time. These data are obtained from the past meteorological data of the General Directorate of State Meteorological Affairs (DMI), and from the studies made by General Directorate of Electric Power Resources Survey and Development Administration (EIE), and by TR Ministry of Energy and Natural Resources and General Directorate of Renewable Energy. (www.eie.gov.tr).

Criteria C1 is Self-consumption and C2 is warehouse roof space were obtained directly from the company. Data were obtained for four out of ten criteria, while the other six criteria were asked to be scored by experts. The wind potentials of the regions, criteria A4 is also obtained from the General Directorate of State Meteorological Affairs (www.eie.gov.tr/yekrepa/repa-duyuru_01.html). However, since the winding potential varies considerably with the land, these data were not used directly but presented to the experts to use the expert opinion.

In the first step, the A1, A2, C1 and C2 criteria were directly taken as , while for the other criteria, opinions of the three experts were taken. The geometric mean of the scores of three experts was taken. In the second step, normalization was carried out with the data that were obtained. All criteria is about maximazing the the benefit in other words maximizing the electricity produced by solar transformation of warehouse. So criteria B1 is taken as how small is the risk of shadowiness for the alternative warehouse. The larger score of an alternative from B1 criteria shows that the shadowiness risk is smaller. For example Istanbul warehouse has the lowest score from criteria B1 as there are huge buildings around the Istanbul warehouse and new huge buildings may be constructed to the land near the warehouse. Standard Decision Matrix which is formed after normalization is seen in Table 2.

	Criteria									
Alternatives	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**
Istanbul	0,371	0,365	0,293	0,473	0,114	0,279	0,520	0,838	0,182	0,455
Izmir	0,412	0,446	0,528	0,510	0,454	0,488	0,404	0,207	0,284	0,520
Adana	0,431	0,441	0,469	0,328	0,454	0,418	0,346	0,370	0,257	0,195
Samsun	0,368	0,345	0,117	0,437	0,511	0,279	0,346	0,175	0,241	0,325
Ankara	0,406	0,390	0,352	0,291	0,227	0,348	0,404	0,159	0,219	0,195
Antalya	0,454	0,450	0,528	0,364	0,511	0,557	0,404	0,249	0,845	0,585

Table 2. Normalized Matrix

In the next step, the weighted matrix was obtained. The weights were obtained from Table 1. The weighted normalized matrix is shown in Table 3.

	Criteria									
Alternatives	**A1**	**A2**	**A3**	**A4**	**B1**	**B2**	**B3**	**C1**	**C2**	**C3**
Weight	**%31,9**	**%19,9**	**%5,0**	**%2,8**	**%15,2**	**%3,3**	**%7,2**	**%1,4**	**%4,4**	**%8,9**
Istanbul	0,118	0,073	0,015	0,013	0,017	0,009	0,037	0,012	0,008	0,040
Izmir	0,132	0,089	0,027	0,014	0,069	0,016	0,029	0,003	0,012	0,046
Adana	0,138	0,088	0,024	0,009	0,069	0,014	0,025	0,005	0,011	0,017
Samsun	0,117	0,069	0,006	0,012	0,078	0,009	0,025	0,002	0,011	0,029
Ankara	0,130	0,078	0,018	0,008	0,035	0,011	0,029	0,002	0,010	0,017
Antalya	0,145	0,090	0,027	0,010	0,078	0,018	0,029	0,003	0,037	0,052

Table 3. Weighted Normalized Matrix

Negative and positive ideal solution values are shown in Table 4.

Ideal Solution Values	0,145	0,090	0,027	0,014	0,078	0,018	0,037	0,012	0,037	0,052
Negative Ideal Solution Values	0,117	0,069	0,006	0,008	0,017	0,009	0,025	0,002	0,008	0,017

Table 4. Ideal Solution Values

Ideal distances for each alternative (S^*), negative ideal distances (S^-), and proximity to the ideal solution (C^*), and the ranking are shown in Table 5.

	S^*	**S^-**	**C^***	**Ranking**
Istanbul	0,07645	0,02993	0,2814	5
Izmir	0,03224	0,06834	0,6794	2
Adana	0,04741	0,06174	0,5656	3
Samsun	0,05631	0,06177	0,5231	4
Ankara	0,06719	0,02624	0,2809	6
Antalya	0,01231	0,08613	0,8749	1

Table 5. Result Values

According to Table 5, the best alternative to be converted into a solar warehouse is Antalya warehouse. The second place is İzmir, and the third place is Adana. The last three alternatives are Samsun, İstanbul and Ankara. So it can be said that the best alternative to be turned in to a solar warehouse is Antalya warehouse. However, this ranking is associated with ten solar criteria. Even though all criteria are about maximizing electricity production, none of them is directly about payback period.

This ranking can be compared with payback period of the investment. A ranking according to the payback period is developed as well. Considering that a facility with an installed capacity of 1 MWp can be installed at an investment cost of 975,000 USD with prices of 2017, the production capacities and annual monetary returns in the same regions are only as follows according to the data of the sunbathing potential (http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php). So investment cost and yearly production (kwh/year) is obtained for six alternatives and shown in the second and third columns of Table 6 consequently. The fourth column of Table 6. demonstrates annual income. Turkey government buys the electricity with a price of 0,133 $ per kwh. For example Istanbul warehouse produces 1.300.000 kwh and sells it to the government with a price of 0,133$ per kwh and consequently will yield (0,133 ($/kwh)*1.300.000 (kwh/year)=172.900 $/year which is illustrated n the fourth column. If we divide the investment cost (975.000 $) to yearly income (172.900 $/year) the result will be the payback period (5,64 years) which is shown on the fifth column. As investment cost is the same for all alternatives, ranking may be done by yearly income or by payback period. Instead of payback method self-consumption can be used however it is already used as a criterion in TOPSIS method. As seen on Table 6. the best alternative is Antalya warehouse.

Alternative	Investment cost ($)	Production (kwh/year)	Income (USD/year)	Payback period of investment (years)	Ranking
İstanbul	975.000	1.300.000	172.900	5,64	5
İzmir	975.000	1.540.000	204.820	4,76	3
Adana	975.000	1.560.000	207.480	4,70	2
Samsun	975.000	1.190.000	158.270	6,16	6
Ankara	975.000	1.430.000	190.190	5,12	4
Antalya	975.000	1.640.000	218.120	4,47	1

Table 6. Sorting Alternatives by Investment Return Times

When Table 5 and Table 6 are compared, it is seen that the first row has not changed. According to both methods, Antalya is seen as the best alternative. Although the best alternative is the same according to the two rankings, the remaining of two ranking lists is different. According to TOPSIS method, the second is İzmir warehouse, while according to the payback period method it is Adana warehouse. It is expected to face some differences in two rankings because the criteria are not the same for two methods. TOPSIS is a more integrative method as it considers ten criteria.

6. Conclusion and Recommendations

This study focuses on the solar warehouse which is a new concept for sustainable warehousing. As a warehouse consume huge amount of electricity and transforming a warehouse to a solar one will reduce this consumption by producing own electricity, it is thought that warehouses will be transformed to solar ones in future. The aim of the study is to determining which depot should be selected to be converted to a solar one. TOPSIS method is used for the ranking of alternatives. This method considers ten solar warehouse location criteria. It can be said that this method contains both economic and environmental aspects. While economic aspect is about maximizing electricity production, using renewable energy by reducing environmental effects can be regarded as environmental aspect.

The results of this method is compared with the results of an another method; payback period. Although the best alternative is the same according to the two rankings, the remaining of two ranking lists is different as it is expected.

One of the main constraints of the study is that some of the evaluations are made subjectively, as all multi-criteria decision-making problems. In addition, the fact that the criteria used in this study are only solar and economic criteria, which can be considered as another constraint. Two methods may be integrated and also the social dimension of sustainability may be considered as another criterion in further research. With larger models, in future studies, an integrative criterion ranking can be made, considering not only solar criteria but also other criteria.

References

Ageron, B., Gunasekaran, A., & Spalanzani, A. (2012). Sustainable supply management: An empirical study. International Journal of Production Economics, 140(1), 168-182.

Ala-Harja, H., and P. Helo. 2014. "Green Supply Chain Decisions–Case-based Performance Analysis from the Food Industry."Transportation Research Part E: Logistics and Transportation Review 69: 97–107.

Amjed, T. W., & Harrison, N. J. (2013). A Model for sustainable warehousing: from theory to best practices. In Proceedings of the International Decision Sciences Institute and Asia Pacific DSI Conference (pp. 1-28).

Awasthi, A., Chauhan, S. S., Goyal, S. K. (2011). "A multi-criteria decision making approach for location planning for urban distribution centers under uncertaint", Mathematical and Computer Modelling, 53(1-2), 98-109.

Bowersox D. J., Cloos D. J., Cooper M. B.,(2002), Supply Chain Managment, Mc Graw Hill.

Boztepe (2018), Yeşil Lojistikte Depo Yeri Seçimi, Yayımlanmamış Dotora Tezi, İstanbul Üniversitesi, SBE.

Boztepe R., Özçakar, N., Çetin, O., (2015) "Depo Yeri Seçiminde Solar Kriterlerin Karşılaştırılması", V. Ulusal Üretim Araştırmaları Sempozyumu, İstanbul Ticaret Üniversitesi, 14-16 Ekim, İstanbul.

Carter, C. R., & Rogers, D. S. (2008). A framework of sustainable supply chain management: moving toward new theory. International journal of physical distribution & logistics management, 38(5), 360-387.

Chopra, S., Meindl, P., (2016) Supply Chain Management, Pearson, sixth edition.

Choudhary, D., & Shankar, R. (2012). "An STEEP-fuzzy AHP-TOPSIS framework for evaluation and selection of thermal power plant location: A case study from India". Energy, 42(1), 510-521.

Ciliberti, F., Pontrandolfo, P., & Scozzi, B. (2008). Investigating corporate social responsibility in supply chains: a SME perspective. Journal of cleaner production, 16(15), 1579-1588.

Dadhich, P., A. Genovese, N. Kumar, and A. Acquaye. 2015. "Developing Sustainable Supply Chains in the UK Construction Industry: A Case Study." International Journal of Production Economics 164: 271–284.

Dekker, R., J. Bloemhof, and I. Mallidis. 2012. "Operations Research for Green Logistics – An Overview of Aspects, Issues, Contributions and Challenges." European Journal of Operational Research 219 (3): 671–679.

Demirel T, Demirel NC¸ Kahraman C., (2010) Multi-criteria Warehouse location selection using Choquet integral. Expert Syst Appl 37(5):3943–3952

Ertuğrul, İ., Karakaşoğlu, N.. (2008). "Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection", Int. J. Adv. Manuf. Technol., 39, pp.783-795.

Foroozesh, N., Tavakkoli-Moghaddam, R., & Mousavi, S. M. (2018). A novel group decision model based on mean–variance–skewness concepts and interval-valued fuzzy sets for a selection problem of the sustainable warehouse location under uncertainty. Neural Computing and Applications, 30(11), 3277-3293.

Fekete, P., S. Martin, K. Kuhn, and N. Wright. 2014. "The Status of Energy Monitoring in Science and Industry by the Example of Material Handling Processes." Business, Management and Education 12: 213–227.

Heizer, J., Render, B. ve Munson, C. (2017). Operations Managment, Pearson.

Jha, M. K., Raut, R. D., Gardas, B. B., & Raut, V. (2018). A sustainable warehouse selection: an interpretive structural modelling approach. International Journal of Procurement Management, 11(2), 201-232.

Kahraman C., Ruan D., Doğan I. (2003) Fuzzy group decisionmaking for facility location selection. Inf Sci 157:135–153.

Kannan, D., de Sousa Jabbour, A. B. L., & Jabbour, C. J. C. (2014). Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company. European Journal of Operational Research, 233(2), 432-447.

Knez, M., Bajor, P., & Seme, S. (2011). Green Logistics–A Solar Warehouse Concept. Logistics & Sustainable Transport, 2(2).

Krajewski, L. J., Ritzmann, L. P., Malhotra, M. K. (2013). Operations Management, England: Pearson.

Meade, L., & Sarkis, J. (1998). Strategic analysis of logistics and supply chain management systems using the analytical network process. Transportation Research Part E: Logistics and Transportation Review, 34(3), 201-215.

Makris, P. A., A. P. Makri, and C. G. Provatidis. 2006. "Energy-saving Methodology for Material Handling Applications." Applied Energy 83 (10): 1116–1124.

Meneghetti, A., and L. Monti. 2013. "Sustainable Storage Assignment and Dwell-point Policies for Automated Storage and Retrieval

Systems." Production Planning & Control 24 (6): 511–520.

Meneghetti, A., and L. Monti. 2014. "Multiple-weight Unit Load Storage Assignment Strategies for Energy-efficient Automated Warehouses." International Journal of Logistics Research and Applications 17 (4): 304–322.

Meneghetti, A., and L. Monti. 2015. "Greening the Food Supply Chain: An Optimisation Model for Sustainable Design of Refrigerated Automated Warehouses." International Journal of Production Research 53 (21): 6567–6587.

Meneghetti, A., E. D. Borgo, and L. Monti. 2015a. "Decision Support Optimisation Models for Design of Sustainable Automated

Warehouses." International Journal of Shipping and Transport Logistics 7 (3): 266–294.

Özdemir M., Topsis, (2014). Çok Kriterli Karar Verme Yöntemleri, Edt:Yıldırım, F. B., Önder, B., Dora Yayıncılık,

Raut, R. D., Narkhede, B. E., Gardas, B. B., & Raut, V. (2017). Multi-criteria decision making approach: a sustainable warehouse location selection problem. International Journal of Management Concepts and Philosophy, 10(3), 260-281.

Ries, J. M., Grosse, E. H., & Fichtinger, J. (2017). Environmental impact of warehousing: a scenario analysis for the United States. International Journal of Production Research, 55(21), 6485-6499.

Sezer F, Özkan BALİ, Gürol P (2016) Hazardous materials warehouse selection as a multiple criteria decision making problem. J Econ Bibliogr 3(1):63–73

Stevenson, W. J., (1996), Production Operations Management, McGraw Hill.

Tan, K. S., Ahmed, M. D., & Sundaram, D. (2009). Sustainable warehouse management. In Proceedings of the International Workshop on Enterprises & Organizational Modeling and Simulation (p. 8). ACM.

Tan, K. S., M. Daud Ahmed, and D. Sundaram. 2010. "Sustainable Enterprise Modelling and Simulation in a Warehousing Context."

Business Process Management Journal 16 (5): 871–886.

Tappia, E., G. Marchet, M. Melacini, and S. Perotti. 2015. "Incorporating the Environmental Dimension in the Assessment of Automated Warehouses." Production Planning & Control 26 (10): 824–838.

Ulukan, H. Z., ve Kop, Y. (2009). "Multi-criteria decision making (MCDM) of solid waste collection methods using life cycle assessment (LCA) outputs". In Computers & Industrial Engineering, 2009. CIE 2009. International Conference on (pp. 584-589). IEEE.

Uysal, F., & Tosun, Ö. (2014). Selection of sustainable warehouse location in supply chain using the grey approach. IJIDS, 6(4), 338-353.

Vachon, S., & Klassen, R. D. (2006). Green project partnership in the supply chain: the case of the package printing industry. Journal of Cleaner production, 14(6), 661-671.

Wanjiru, W. S., Kiarie, D., Marendi, P.(2018) Role of Strategic Procurement Practices On Performance of Nyandarua County Government. International Journal of Human Resources and Procurement, 7(4), 64-74.

Yavuz, S., ve Deveci, M. (2014). Bulanik TOPSIS ve Bulanik VIKOR Yöntemleriyle Alisveris Merkezi Kurulus Yeri Seçimi ve Bir Uygulama/Selection of Shopping Center Location with The Methods of Fuzzy VIKOR and Fuzzy TOPSIS and An Application. Ege Akademik Bakis, 14(3), 463.

Zhu, Q., & Sarkis, J. (2004). Relationships between operational practices and performance among early adopters of green supply chain management practices in Chinese manufacturing enterprises. Journal of operations management, 22(3), 265-289.

Zsidisin, G. A., & Siferd, S. P. (2001). Environmental purchasing: a framework for theory development. European Journal of Purchasing & Supply Management, 7(1), 61-73.

Żuchowski, W. 2015. "Division of Environmentally Sustainable Solutions in Warehouse Management and Example Methods of Their Evaluation." LogForum 11 (2): 171–182.