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An application of topsis methodology for smart, green logistics in warehouse

Abstract

Logistics is a keyword for the organisation and optimisation of a complex operation. Nowadays, optimising the cost for a long term in combination with eco- friendly solutions is the new purpose of the research topics in logistics. This new point of view, which focuses on minimising and reducing waste, gases, processes, and vibrations, is named green logistics. The main goal of this paper is to give a new, "green" direction to logistics in warehouses and to provide the best solution by analysing the various options using the Multi-Criteria Analysis method concerning the idea of using green logistics and making a warehouse more environmentally friendly.

Keywords: Logistics, warehouse, green logistics, MCDM (Multi-Criteria Analysis Method) methods, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

Introduction

In the past, not all the commodities were produced or were available where people wanted them to be. Most of them were available only at fixed locations and at certain times of the year. These limitations forced people to think about new solutions and alternative ideas (Pulevska-Ivanovska 2009; Bartholdi–Hackman 2014).

People started to improve the production efficiency of local goods and began to import products that were not locally produced. Consequently, logistic systems started to develop, and their importance increased while a high level of foreign trade and many other benefits were assured.

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The logistics processes affect, directly or indirectly, almost every sphere of human activity. All areas of logistics have a significant impact on the final price. As customers, we tend to notice logistics only when there is a problem. We tend to ignore the role of logistics in our own lives until something goes wrong (Pulevska-Ivanovska 2009; Bartholdi–Hackman 2014).For instance, when a customer orders flowers online for his wife and they arrive too late, even though a punctual delivery was promised (Hompel–Schmidt (2009).

Getting the right goods or services to the right place, at the right time and in the desired condition at the lowest cost while having the highest return on the investment, is the well-known mission of logistics Pulevska-Ivanovska 2009. Effective logistics management seizes any opportunity available to increase the value (Pulevska-Ivanovska 2009; McKinnon et al. 2012).

The objective of this paper

Warehousing is the act of storing goods that are going to be sold or distributed later. Since the goal is storage with additional activities, warehouses use specialised equipment that offers manipulation and safe storage of the goods. A good warehouse strategy is focused on optimising movement, space, and extra cost (Bartholdi–Hackman 2014; Hompel–Schmidt 2009). According to research in the field of material flow, the most crucial activity, which is very hard to automate entirely, is the correct order-picking (Živanić et al. 2014) . Nowadays, in a world where technology permeates all spheres, the warehouse is not out of the grid either (Ritchie–Roser 2019; Stojanović 2012). The question of how technology in the warehouse evolved is exciting but even more intriguing is the next step. Would technology replace human activity in the warehouse?

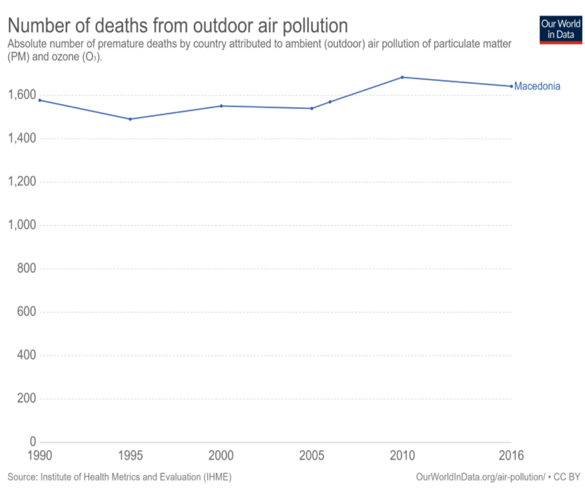
Nowadays, the available technologies use hardware such as sensors, scanners, and GPS trackers to establish a precise relation between inventory and associates in the warehouse at any time. Internet availability on handheld devices enables quick connection and procession of the data. This technology is a revolution in supply chain management since it provides visibility and precision. Users can get a clear picture by tracking through GPS location devices and therefore make optimal plans for warehousing (Stojanović 2012) . Sensor technology has made it possible to map each warehouse, to analyse inventories and reveal the location of each product. Even though businesses may not be able to implement all of the changes immediately, smart technology is the perfect opportunity for flexible changes in warehousing (McKinnon et al. 2012; Huston 2013).

Pollution in warehouses

Air pollution can be defined as the emission of harmful substances into the atmosphere. This broad definition covers several pollutants, including sulphur dioxide (SO_2), nitrogen oxides (NO_x), ozone (O_3), carbon monoxide (CO), carbon dioxide (CO_2) and other greenhouse gases. Same air pollutants can be complex and specific since some pollutants act as precursors to others. For example, SO_2 and NO_x can react in the Earth's atmosphere to form particulate matter (PM) compounds (Snow 1998 [2011]; Ritchie–Roser 2019).

The warehousing industry affects air quality and an increased carbon dioxide emission from the energy sector is caused by the expansion of warehousing. Research indicates that worldwide one of the top contributors to lung cancer is the diesel trucks used in the warehousing industry (Bouhlal 2005; Arvis et al. 2018). The World Logistics Centre estimates that one in 10,000 residents who live near warehouses and one in 50,000 within the wider area of warehouses could develop cancer (Arvis et al. 2018). Air pollution in Skopje is one of the critical topics of the World Health Organization (WHO). They recently ranked Skopje the third most polluted city in Europe. The organisation's data show that Skopje's annual air pollution is 60 per cent higher than EU guidelines, and four times higher than the WHO guidelines *(Figure 1)*, (Snow 1998 [2011]; Ritchie–Roser 2019).

Figure 1: *Number of deaths from outdoor air pollution*



Source: Institute of Health Metrics and Evaluation (IHME)

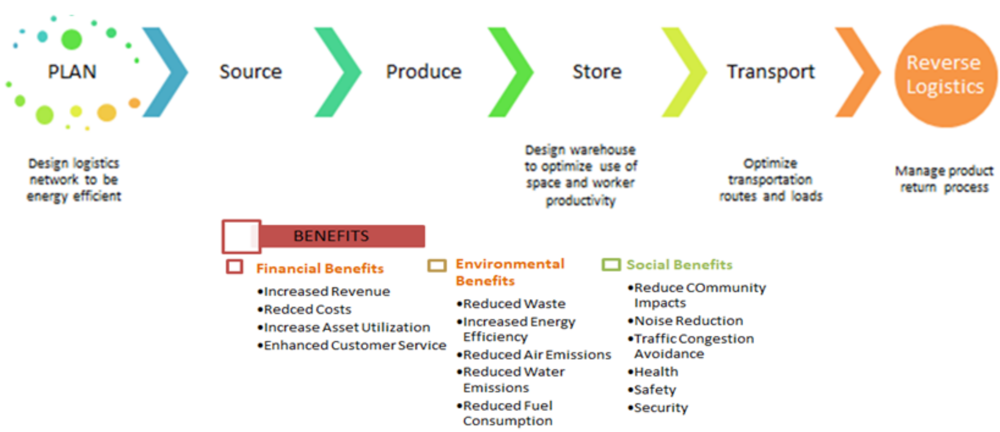
Logistics warehouse layout analysis

Improving each aspect of the work in a warehouse requires careful attention to details. Even though technology can affect the progress of storage methods, it cannot change the essential functions. New data processing systems cannot reform inadequate information management procedures, e. g. the crane cannot clean the dirty warehouse (Beškovnik–Jakomin 2010).

Besides air pollutants, many other elements are harmful to the environment. For example, the adverse effects of noise cause problems in communication, decreased concentration, i. e. reduce overall productivity, as well as mental and cardiovascular problems. The last few years, the European Union has introduced rigorous measures to limit noise in road transport and workplaces.

Green Logistics is logistics, the purpose of which is to preserve the environment. Global warming, pollution, natural resource constraints, transportation, waste problems urge us to pay serious attention to reducing the pressure on the environment. Rational use of waste materials and rationalisation of logistics processes are two different ways in which we can reduce pollution. There are several contradictions in green logistics. The purpose of logistics is minimising cost and saving time while increasing reliability and flexibility through the use of green logistics *(Figure 2)*. Yet, as shown in this figure, there is no cost-cutting (Bouhlal 2005; Arvis et al. 2018).

Figure 2: *Benefits of green logistics*



Time is usually the most important result of good logistics operations, and by reducing time, productivity is increased (Bouhlal 2005). Many studies believe that "green vehicle technology and mechanisation" is the most promising and has the most significant potential for reducing CO and other harmful emissions (Beškovnik–Jakomin 2010).

Although they appear to be very simple and easily applicable, they are in fact, interdependent and usually inversely proportional; for example, the NO_x reduction contributes to increased CO.

Green aspects in warehouses

The energy today is obtained mainly from fossil fuels: oil, natural gas, and coal. Yet, solar energy technology has highly improved: today; solar cells are six times more efficient than they were 30 years ago (Bhattacharjee 2015). How can solar energy help economic growth, public health, and the environment? How can solar energy be part of green logistics?

According to some research, green logistics can be used for energy efficiency in warehouses in three aspects. The first and the simplest level of a green warehouse is an energy-efficient building with minimum requirements. This aspect focuses on the internal factors of the green warehouse such as heating, lighting, air change and mechanical handling equipment. We can say that this is clean energy technology. The main goal of clean energy technology is to make the roof and window design more able to aid conservation of sunlight and to use night LED lighting, in other words, to use the sun's energy without any particular investment. The next stage for creating a low-emission and green energy warehouse is to consume renewable and green energy to lower carbon emissions (Baker–Marchant 2015).

Depending on the function and the nature of the warehouse storage, local weather, design and in-house activities, each warehouse has different requirements. The primary sources of energy for heating/cooling systems in the warehouse come from gas, fuel, and electricity (Richards–Riding 2015; Bhattacharjee 2015).

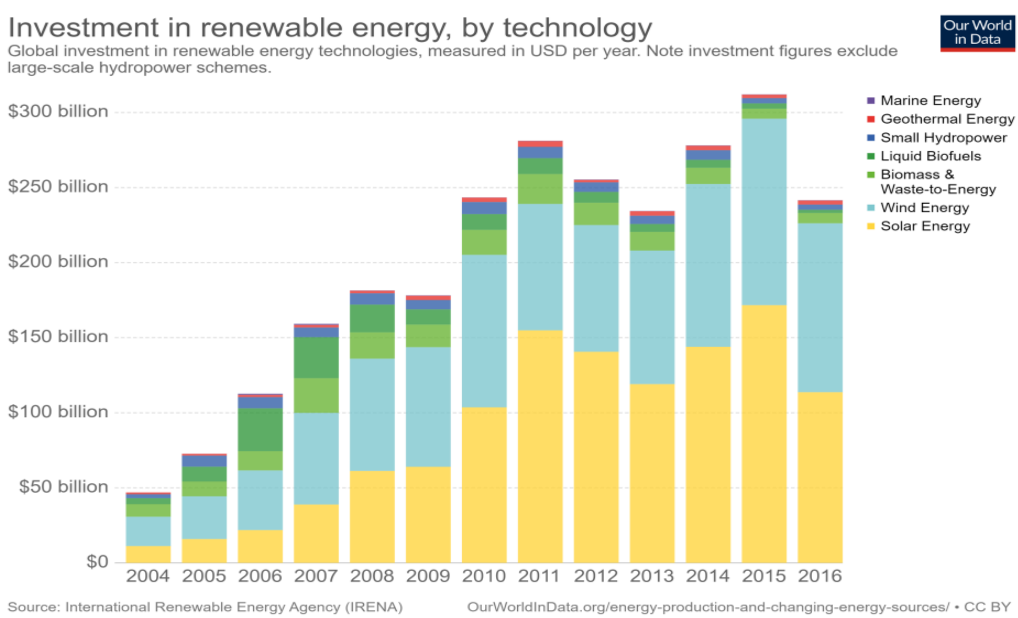
Every step towards giving rise to green warehousing is a step forward, but the most promising methods of the future green warehouse include energy self-production and sustainable building design (Richards–Riding 2015).

For small businesses, the first step to take in the interest of smart and green logistics is to optimise the routes they take. Instead of picking products for multiple orders, they can handle one order at a time: moving to the right shelf, at the right time, selecting the product, and so on. This process will be repeated several times throughout the day. The proposed analytical model is based on the publication (Zivanic et al. 2019) that described a calculation of the picking time using the bound cavities method. The model can be used in the initial plan to carry out the analysis, estimates of the total picking time, and potential savings. The bound cavities method, applied in the above, can be used with adjustments, for other purposes in the warehouses.

Value of "green" logistics strategy

A modern, futuristic warehouse can partially or entirely produce the necessary energy itself by using renewable energy sources. This can be a perfect approach to decrease emissions and greenhouse gas as well as energy costs. Modern, smart, and clean sources of energy include solar, biomass, and wind power (Richards–Riding 2015). Nonetheless, due to the extensive capital investment, self-production of energy in a warehouse, for now, is only an environmental-friendly method and not a cost-efficient one. Consequently, choosing an affordable way to self-produce energy is a hard task. Solar panels are a costly investment which will pay back in about 15-20 years.

Figure 3: *Global investments in renewable energy technologies, measured in USD per year*



Source: International Renewable Energy Agency (IRENA), Our World in Data

On the other hand, electricity wind turbines are much lower in price, and the investment generally pays off within five years. However, before managers decide on a green investment, a comprehensive analysis of payback is required (Baker–Marchant 2015). The investment in energy self- production is a good choice only for massive warehousing, and if governments provide the necessary incentives as well as enforce compulsory regulations *(Figure 3)*. It seems that the politics and power play of governments play a vital role in green energy generation (Richards–Riding 2015).

Results and discussion of implementation the MCDM methods (TOPSIS)

Multi-Criteria Decision-Making (MCDM) is an important potential tool for analysing complex problems, because of its inherent ability to judge different alternatives (Choice, strategy, policy, scenario) by using various criteria to select the best-suitable option or alternative. These alternatives may be further explored in depth for their final implementation. In this paper, the TOPSIS method is used. TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) is designed as an alternative to the ELECTRE method and can be considered as one of its most widely accepted variants. The basic concept of the TOPSIS method is that the selected alternative should have the shortest geometric distance from the ideal solution and the farthest geometrics distance from the negative-ideal solution (Jakimovska 2013).

There are some steps which represent the TOPSIS method procedure. The paper will present how to select the best investment through an example.

Table 1: *Represents TOPSIS information*

Alternatives	Criteria			
	C_1	C_2	...	C_j
A_1	X_{11}	X_{12}	...	X_{1j}
A_2	X_{21}	X_{22}	...	X_{2j}
.	.	.	.	.
.	.	.	.	.
.	.	.	.	.
A_i	X_{i1}	X_{i2}	...	X_{ij}
W	W_1	W_2	...	W_j

Where:

A_1, A_2, … , A_j represent possible alternatives from which a decision-maker has to choose,
C_1, C_2, … , C_j are criteria with which alternative performance are measured,
X_{ij} is a rating of alternative A_i with respect to criterion C_j,
W_j is the weight of the criteria C_j,
i=1, … , m is the number of alternatives,
j=1, … , n is the number of criteria.

When some of the criteria are shown as qualitative values, they need to be changed into quantitative values. For that purpose, a numerical scale is used, as shown in *Table 2.*

Table 2: *Transformation of linguistic scales into quantitative values*

Linguistic scale	Quantitative value	
	Benefit – max	Cost – min
Very high	9	1
High	7	3
Average	5	5
Low	3	7

For presenting the MCDM methods, as one of the possible ways of ranking green solutions, we chose three alternatives (A_1, A_2, A_3) and four evaluating criteria (C_1, C_2, C_3, C_4), which are mentioned above.

Table 3: *Raw data*

Alternatives max		Efficiency	Costs	Payback time	Implementation (easy, medium, hard)
		min	min	max	
A_1	Clean energy	5	7	1	1
A_2	Smart technology	9	1	7	7
A_3	Self-produced energy	7	3	7	7
Weighting factor		0.25	0.35	0.25	0.15

Qualitative dates in *Table 3* are changed into quantitative ones, using the numerical scale in *Table 2*. To make a normalised decision matrix (step 1), *(Table 4)* calculation formula is applied (1). All tables were created in Microsoft Office Excel.

$$\overline{X}_{ij} = \frac{X_{ij}}{\sqrt{\sum_{j=1}^{n} X_{ij}^2}}. \tag{1}$$

In step two, the calculation of weighted normalised matrix v_{ij} of each criterion is made using the following formula (2):

$$v_{ij} = \overline{X}_j \times W_j . \qquad (2)$$

Table 4: *Calculated weighted normalised matrix v_{ij}*

	Efficiency	**Cost**	**Payback time**	**Implementation (easy, medium, hard)**
Alternatives	max	min	min	max
A_1: Clean energy	0.100402	0.318963	0.025125945	0.015075567
A_2: Smart technology	0.180724	0.045566	0.175881618	0.105528971
A_3: Self-produced energy	0.140563	0.136698	0.175881618	0.105528971

Step three *(Table 5)* is the calculation of the ideal best and ideal worst value.

Table 5: *Calculation of the ideal best (V^+) and ideal worst (V^-) value*

	Efficiency	**Cost**	**Payback time**	**Implementation (easy, medium, hard)**
Alternatives	max	min	min	max
A_1: Clean energy	0.025101	0.111637	0.006281486	0.002261335
A_2: Smart technology	0.045181	0.015948	0.043970404	0.015829346
A_3: Self-produced energy	0.035141	0.047844	0.043970404	0.015829346
V^+	**0.045181**	**0.015948**	**0.006281486**	**0.015829346**
V^-	**0.025101**	**0.111637**	**0.043970404**	**0.002261335**

In step four, we calculated the Euclidean distance from the ideal best (S_i^+), formula (3) and ideal worst (S_i^-), formula (4) value. The results are shown in *Table 6.*

$$S_i^+ = [\sum_{j=1}^{m} (v_{ij} - v_j^+)^2]^{0.5} . \qquad (3)$$

$$S_i^- = [\sum_{j=1}^{m} (v_{ij} - v_j^-)^2]^{0.5} . \qquad (4)$$

Table 6: *The Euclidean distance from the ideal best (S_i^+), and ideal worst value (S_i^-)*

	Efficiency	Cost	Payback time	Implementation (easy, medium, hard)	S^+	S^-
Alternatives	max	min	min	max		
A_1: Clean energy	0.02510	0.111637	0.006281486	0.002261335	**0.097773**	**0.037689**
A_2: Smart technology	0.04518	0.015948	0.043970404	0.015829346	**0.037689**	**0.09871**
A_3: Self-produced energy	0.03514	0.047844	0.043970404	0.015829346	**0.050385**	**0.065988**
V^+	0.04518	0.015948	0.006281486	0.015829346		
V^-	0.025101	0.111637	0.043970404	0.002261335		

The last step in the implementation of the TOPSIS method is the calculation of Performance Score, Formula (5). The results are shown in *Table 7.*

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-}. \tag{5}$$

Table 7: *Calculation of Performance Score*

S^+	S^-	P_i
0.097773	0.037689	0.278225
0.037689	0.09871	0.723686
0.050385	0.065988	0.567039

In the end, we ranked the P_i values *(Table 8).* From *Table 8,* we can conclude that the ideal option, in this example, is alternative no. 2 (smart technology).

Table 8: *Rank of P_i values*

S^+	S^-	P_i	Rank
0.097773	0.037689	0.278225	3
0.037689	0.09871	0.723686	1
0.050385	0.065988	0.567039	2

The above is a simple example of how to decide on the best option for investment in our situation. In a real case, we can apply more criteria, and use the MCDM methods to select the best option for us.

Conclusion

The research outcome can provide insightful information and directions for green logistics. These data can help to create a global picture of the problems and to keep track of the situation of logistics and energy efficiency while enabling a better decision-making process in the future. Even though the main objective of this paper is implementing energy self-production solutions, this paper suggested using different, multidisciplinary approaches. By applying the appropriate mathematical models and criteria, our results showed where investment is advisable. Every idea is a new approach, and there is always a need for continuous research on green energy sources.

According to data released on 24 August by the U.S. Energy Information Agency (EIA), renewable energy in the U.S. through the first half of 2016, including hydro-electric power, biomass, geothermal, wind, and solar (including distributed solar) power, provided for 16.9 per cent of electricity generation. In 2015, that number was 13.7 per cent. Non-hydro renewable energy provided for 9.2 per cent of U.S. electricity generation through the first half of 2016. For 2015 it was 7.6 per cent. (Daniel Fleischmann [2016]: Renewable Energy Was 16.9 Percent of US Electric Generation in the First Half of 2016, Renewable Energy World.)

Although modern warehouses in the world are increasingly automated, still in most cases, humans cannot be replaced by machines.

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