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Selected methods of location logistic distribution centers in food supply chains

Wybrane metody lokalizacji logistycznych centrów dystrybucyjnych w łańcuchach dostaw żywności

Abstract. The paper presents method of selecting the location of a logistics distribution center in food supply chains. This selected method examines the problem of choosing a location in terms of total costs or the factor of space, more precisely − distance. The paper presents the possibility of using method. For this purpose, a short review of the literature is presented, then at the end of the article, the possibility of using method to solve the problem is shown.

Key words: food supply chain, location, logistic center

Synopsis. W pracy przedstawiono jedną z wielu prezentowanych w literaturze przedmiotu metodę wyboru lokalizacji logistycznego centrum dystrybucyjnego w łańcuchach dostaw żywności. Metoda ta rozpatruje problem wyboru lokalizacji w aspekcie kosztów całkowitych lub czynnika przestrzeni, a dokładniej – odległości. W pracy przedstawiono możliwość zastosowania tej metody. W tym celu przedstawiono krótki przegląd literatury, następnie na końcu artykułu pokazano możliwość zastosowania metody do rozwiązania problemu.

Słowa kluczowe: łańcuch dostaw żywności, lokalizacja, centrum logistyczne

Introduction

The agri-food supply chain concept was first proposed by scholars in the agricultural economics and management discipline [Salin 1998, Mardsen et al. 2000, Manzini and Accorsi 2013]. The commonly used terms to describe this idea include agricultural supply chain, agricultural value chain, food supply chain, and food value chain. The food supply chain is composed of a wide diversity of products and companies which operate in different markets and sell a variety of food products [Vlajic et al. 2012, van der Vorst 2000]. It combines activities whose primary purpose is to ensure buyer satisfaction and profit to enterprises participating in the flow of products and services from the sphere of primary agricultural production (farmer) to the consumer (Figure 1). All sectors, which belongs and create the food supply chain, are important from the economically point of view [Yu and Nagurney 2013]. There is many interactions between this sectors, purchasers and suppliers appear in every link in the food supply chain [Bukeviciute et al. 2009, Nicholson et al. 2011].

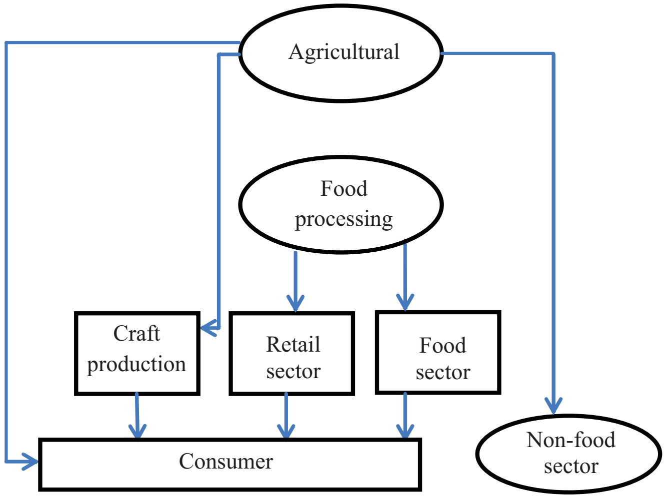

Figure 1. Schematic representation of the food supply chain
Rysunek 1. Schemat łańcucha dostaw żywności
Source: [Bukeviciute et al. 2009].

The emergence of distribution centers and logistics centers in recent years has become a common phenomenon resulting from the ongoing global economic processes. They replace in their assumption the existing warehouse retailers, as well as in the version of manufacturers of warehouses of finished products [Ahumada and Villalobos 2009, Kozierska 2016]. As a result, distribution centers are important in the place of distribution where there is a greater number of participants (both from the side and the recipients). In logistics terminology, there are various definitions of a logistics center, which have their source in attempts at classification, their regulation, distribution, and logistics distribution center [Frechner 2010]. Logistics distribution center, defined in the literature as "a center dealing with the coordination of logistics services and transport over short and long distances, ensuring an integrated transport connection with the flow of information between producers, distributors and consumers, and a control system" [Abt 1996]. In Anglo-Saxon literature, the concept of a distribution center is defined as an object, often smaller than the company's central warehouse, used for the temporary storage of goods and their distribution, often referred to as a distribution warehouse [Viale 1996, Opara 2003].

The problem of location is usually considered in many aspects, and the most common methods of assessment are used to solve it. The selection criteria include:

– labor costs in the regions where facilities are located,
– storage and transport costs,
– required order fulfillment time (service level),

– existing infrastructure (roads, railways, inland waterways, airports),
– distance from procurement markets and customers,
– local taxes and regional development incentives.
– the ability to identify the types of cargo transported.

For the purposes of this work, the distribution center is understood as a spatial object with an organization and infrastructure appropriate for it, so that it allows the economic entity to store, service operations on goods and coordinate transport in order to meet the needs, in the shortest time and at the service cost [van der Vosrt et al. 2009, Grabański 2015].

The analysis of the literature shows that different criteria are used to select the locations of nodal points in the network, and the authors often postulate simultaneous rest in many of the criteria. These approaches are defined as multi-criteria or multi-faceted. In multi-criteria approaches, they are mentioned as the main regulation deciding on the selection of logistics locations [Jezusek and Widera 2001, Wasiak 2004].

Methodology[1]

The literature on the subject presents many methods allowing to determine the location of a logistic distribution center [Liu 1999, Nozick and Turnquist 2001, Kuo 2011, Mousavi et al. 2015, Hu et al. 2020]. The center of gravity method is widely described in the literature on the subject [Zhongyi 2005, Zhang et al. 2009, Ying 2014] . It can be used to define the strategic location of a single logistic facility. This method is especially useful when planning a logistics network, when it is necessary to decide on the location of a production plant, warehouse or store. This method uses the location of individual sending and receiving points in the form of geographic coordinates and the volume of supply and demand at individual points in the network. Optimization in this method consists in determining the location of the facility that will minimize the costs of transporting raw materials, semi-finished products or goods to the facility and exporting finished goods from the facility. The center of gravity method is used when there are many suppliers and many sales markets. The main parameter to be optimized for the center of gravity model is distance. This method does not use the real distance and the most commonly used distance measures are formulas [Kuczyńska and Ziółkowski 2001]:

$$d_{ij}^{p} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}$$

where:
$A_i(x_i, y_i)$, $A_j(x_j, y_j)$ – points R^2.

Usually, the real distance between the points is not less than the distance determined by the taxicab distance and not shorter than the distance determined by the Euclidean

[1] Based on: [Kauf and Tłuczak 2016].

metric [Sherali and Tuncbilek 1992, Goncalves et al. 2014, You et al. 2019]. The differences in the interpretation of both metrics are shown in Figure 2.

It is assumed that the coordinates of location of A_i suppliers (x_{iA}, y_{iA}) and B_j recipients (x_{jB}, y_{jB}), the volumes of deliveries a_i and the demand b_j represented by suppliers and recipients, are known. In addition, it is assumed that the unit, calculated cost of transport to the k_A warehouse and from the warehouse to k_B points of sale will be known.

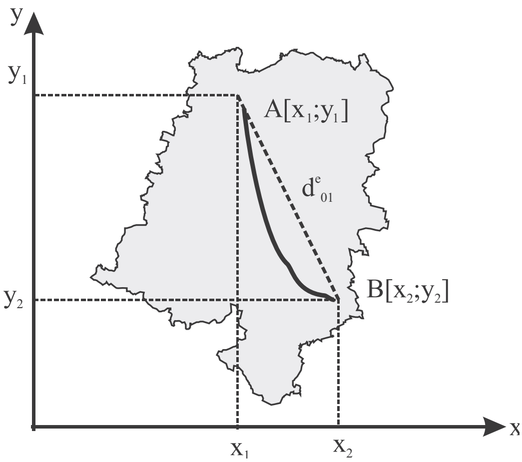

Figure 2. Euclidean, rectangular and real distances A(x_1, y_1), B(x_2, y_2).
Rysunek 2. Odległości euklidesowa, prostokątna i rzeczywista między punktami A(x_1, y_1), B(x_2, y_2).
Source: [Kauf and Tłuczak 2016].

The issue under consideration is based on the minimization of the travel cost function, which is given by the formula:

$$K = \sum_{i=1}^{m} a_i k_i^a d_{i0} + \sum_{j=1}^{n} b_j k_j^b dj_{i0}$$

Looking for a solution to the above optimization task, one should find the coordinates of the location of the distribution center according to the formulas:

$$\overline{x}_0 = \frac{\sum_{i=1}^{m} a_i k_i^A x_i^A + \sum_{j=1}^{n} b_j k_j^B x_j^B}{\sum_{i=1}^{m} a_i k_i^A + \sum_{j=1}^{n} b_j k_j^B}$$

$$x_0 = \frac{237909.84}{12174} = 19.54 \quad \text{and} \quad y_0 = \frac{644756.62}{12174} = 52.96$$

When determining the coordinates of the position of the balanced center of gravity, the calculation of the corrective indicators:

$$x_0 = \frac{\sum_{i=1}^{m} \frac{a_i k_i^A x_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B x_j^B}{d_j^B}}{\sum_{i=1}^{m} \frac{a_i k_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B}{d_j^B}}$$

$$y_0 = \frac{\sum_{i=1}^{m} \frac{a_i k_i^A y_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B y_j^B}{d_j^B}}{\sum_{i=1}^{m} \frac{a_i k_i^A}{d_i^A} + \sum_{j=1}^{n} \frac{b_j k_j^B}{d_j^B}}$$

Example of use of the gravity method

For easier understanding of the procedure for determining the location of the distribution center, we will use an example. We are looking for a location for a distribution center serving the participants (suppliers and recipients) of the food supply chain from all over Poland. We assume that the center cooperates with three suppliers and two recipients. Data needed for calculations: coordinates of recipients and suppliers, size and cost of transport are presented in Table 1. Tables 2−5 show the calculations needed to find the location of the distribution center.

Table 1. Data for the location of the logistics center
Tabela 1. Dane do lokalizacji centrum logistycznego

Suppliers and Recipients	Coordinates		Shipment size (number of pallets)	Unit cost of transport [PLN]
	x_i	y_i		
Supplier A_1	16.17	54.19	520	5.2
Supplier A_2	23.16	53.13	580	5.9
Supplier A_3	19.03	54.03	350	4.8
Recipient B_1	17.03	51.1	480	4.6
Recipient B_2	21.00	52.23	400	5.4

Source: own study.

The given coordinates identify the selected places where the hypothetical suppliers and recipients are. The calculations needed to determine the center of gravity are presented in Table 2, on the basis of which we have that:

$$x_0 = \frac{237909.84}{12174} = 19.54 \quad \text{and} \quad y_0 = \frac{644756.62}{12174} = 52.96$$

Table 2. Setting the center of gravity
Tabela 2. Wyznaczanie środka ciężkości

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Unit cost of transport [PLN]	Transportation cost	Values	Values
	x_i	y_i			a_ik_i; b_jk_j	$x_ia_ik_i$; $x_jb_jk_j$	$y_ia_ik_i$; $y_jb_jk_j$
Supplier A_1	16.17	54.19	520	5,2	2 704	43723,68	146529,76
Supplier A_2	23.16	53.13	580	5,9	3 422	79253,52	181810,86
Supplier A_3	19.03	54.03	350	4,8	1 680	31970,4	90770,4
Recipient B_1	17.03	51.1	480	4,6	2 208	37602,24	112828,8
Recipient B_2	21	52.23	400	5,4	2 160	45360	112816,8
Sum					12 174	237909.84	644756.62

Source: own study.

Based on the data, transport costs can be determined for individual suppliers and recipients. The total cost of transport from suppliers, through the distribution center, to recipients is PLN 34,515.52 (Table 3).

Table 3. Calculation of freight costs
Tabela 3. Obliczanie kosztów przewozu

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Transportation cost	Distances of suppliers and recipients from the center of gravity	Values
	x_i	y_i	a_i; b_j	a_ik_i; b_jk_j	d_i; d_j	$a_ik_id_i$; $b_jk_jd_j$
Supplier A_1	16.17	50.47	450	2 704.00	3.59	9 705,06
Supplier A_2	19.04	49.5	600	3 422.00	3.62	12 392,62
Supplier A_3	18.44	51.36	200	1 680.00	1.18	1 990,44
Recipient B_1	17.29	50.52	700	2 208.00	3.13	6 904,59
Recipient B_2	18.34	51.13	550	2 160.00	1.63	3 522,81
Center of gravity	17.77	50.47		Sum		34 515.52

Source: own study.

The determined coordinates x_0, y_0 will be used in order to determine the corrected coordinates $\overline{x}_0$, $\overline{y}_0$, which will allow for a new location of the distribution center, and this location will reduce transport costs (Table 4):

$$\overline{x}_0 = \frac{1008878.81}{5146.77} = 19.60 \quad \text{and} \quad \overline{y}_0 = \frac{272897.41}{5146.77} = 53.02$$

In the next step, the distance of individual suppliers and customers from the center of gravity should be determined (Table 4).

On the basis of the determined distances and transport costs, it was possible to determine the corrected coordinates of the center of gravity and total cost (Table 5).

The corrected coordinates determined in this way allow for the determination of a new, lower transport cost of: PLN 33,123.15 (Table 5).

Table 4. Determination of the corrected center of gravity
Tabela 4. Wyznaczanie skorygowanego punktu ciężkości

Suppliers and recipients	Distances of suppliers and recipients from the center of gravity	Transpo- -rtation cost	Values	Values	Values $\frac{a_i k_i x_i}{d_i}$ $\frac{b_j k_j x_j}{d_j}$	Values $\frac{a_i k_i y_i}{d_i}$ $\frac{b_j k_j y_j}{d_j}$	Values $\frac{a_i k_i}{d_i}$ $\frac{b_j k_j}{d_j}$
	d_i; d_j	$a_i k_i$; $b_j k_j$	$x_i a_i k_i$; $x_j b_j k_j$	$y_i a_i k_i$; $y_j b_j k_j$			
Supplier A_1	3.59	2 704	43 723.68	146 529.76	12 182.19	40 825.77	753.38
Supplier A_2	3.62	3 422	79 253.52	181 810.86	21 884.44	50 203.82	944.92
Supplier A_3	1.18	1 680	31 970.4	90 770.40	26 984.10	76 613.29	1 417.98
Recipient B_1	3.13	2 208	37 602.24	112 828.80	12 024.72	36 081.21	706.09
Recipient B_2	1.63	2 160	45 360	112 816.80	27 812.36	69 173.32	1 324.40
Sum					100 887.81	272 897.41	5 146.77

Source: own study.

Table 5. Calculation of freight costs for a corrected center of gravity
Tabela 5. Obliczanie kosztów przewou dla korygowanego środka ciężkości

Suppliers and recipients	Coordinates		Shipment size (number of pallets)	Transpo- -rtation cost	Distances of suppliers and recipients from the center of gravity	Values
	x_i	y_i	a_i; b_j	$a_i k_i$; $b_j k_j$	d_i; d_j	$a_i k_i d_i$; $b_j k_j d_j$
Supplier A_1	16.17	54.19	450	2 704.00	3.63	7 830.26
Supplier A_2	23.16	53.13	600	3 422.00	3.56	8 969.82
Supplier A_3	19.03	54.03	200	1 680.00	1.16	880.21
Recipient B_1	17.03	51.10	700	2 208.00	3.21	11 465.21
Recipient B_2	21.00	52.23	550	2 160.00	1.61	3 977.65
Center of gravity	19.60	53.02		Sum		33 123.15

Source: own study.

It should be in mind that the designated coordinates may indicate a place where there will be no infrastructure allowing for the construction of a distribution center. Therefore, the designated coordinates can be treated as an introduction to further search for the best location of logistic distribution centers in food supply chains.

The suggested location of the company's own distribution point, obtained as a result of applying the center of gravity method, should be carefully analyzed. Identifying the location using this method is only the beginning of the proper analysis of the location conditions for your own distribution point.

Summary

Determining the approximate transport costs for the analyzed variants is an element supporting the decision to choose the best location for the distribution center. This is the most important element, the correctness of estimating these costs may significantly affect the final decision. It is possible to determine the cost of transport by simulating the distribution using historical data for the analyzed variants.

The proposed location of the distribution point for the surveyed suppliers and recipients, obtained as a result of applying the center of gravity method, requires a thorough analysis. Determining the location using this method is only the beginning of the proper analysis of the location conditions of your own distribution point. You should carefully check regional and local factors that will have a significant impact on decision making.

An important element is to identify additional location factors that will affect the decision-making. They largely depend on the preparation of the decision maker and the analyst's knowledge. If the decision-maker is unable to specify the factors to be followed when selecting a location, a substantively prepared analyst should indicate factors that may have a significant impact on the location of the distribution center.

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