Optimal Location of Distribution Site Based on Distance

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Abstract: For most companies, successful business operation is based on the location at the right place, in the right region, on the right plot. New investments in land, buildings and material handling equipment are carried out for the longer term. As the global business environment in which a company needs to decide on location is becoming more uncertain every day, it is of huge importance to make a thoughtful and ‘future-proof’ decision on the location for a new distribution site. Allocation can also be defined as a process that results in finding a position for a warehouse, company, production, people, things, and activities in a specific area. A newly built distribution site is impossible to be moved in a short period of time, so the decision on where to build a distribution site, warehouse, or manufacturing plant is of vital and strategic importance.

Keywords: Allocation, distribution site, warehouse, location model

1. Introduction

When setting up a new business or expanding to another region, or planning to make an existing business more efficient, it is important to choose the right location for a business, distribution site, or warehouse. In professional literature, this process is referred to as allocation. The location-allocation problem and its solutions are currently not only subject to research and theoretical consideration, but they are also gaining importance in business and management practice.

Location of such facilities as manufacturing plants, distribution warehouse, or shopping centres can affect material flows in increasingly geographically larger supply chains. They affect the costs associated with such material flows.

2. Allocation

Allocation refers to the location of production process, company, distribution centre, division of production operations and workplaces, and the location of a single-purpose machine or equipment. Allocation can also be defined as a process of determining the location of a warehouse, company, machine, production, people, animals, things, and activities (within a specific area). In terms of distribution logistics, allocation is of strategic and economic importance. A newly built warehouse is impossible to be moved in a short period of time, so the decision on where to build a distribution warehouse, logistics centre, or a manufacturing plant is of vital and strategic importance. [1]

Depending on the location of the warehouse, we distinguish between internal and external warehouses. Internal warehouses are located at the premises of a company, while external warehouses are built outside the company due to lack of space or in order to reduce the distance between suppliers or customers and the company. When deciding on the location of the warehouse, it is necessary to consider the amount of stored material and its potential transportation, length and direction of transport routes, the costs related to the operation of the warehouse, the cost of its building, and the nature of material stored.

Determining the appropriate number of warehouses is very important for the efficiency of logistics chains. Higher number of warehouses reduces average transport distances, reduces the status of "inventory on wheels", smaller quantities are transported and warehouse operating costs. [2] Therefore, when deciding on the number of warehouses, the cost of inventory, warehouse operating costs and costs of transportation are particularly important. Inventory costs grow with the number of warehouses. Warehouse operating costs also grow with the number of warehouses but from a certain number of warehouses, if the company rents the warehouse, the costs decrease due to the discounts provided by the warehouse owner. Shipping costs decrease with a higher number of warehouses but tend to increase at certain point due to decreasing volumes of transport to and from individual warehouses. The relationship between the number of warehouses and different types of costs is shown in Figure 1.

Fig. 1 Relationship between the number of warehouses and different types of costs.

Source: [3]

The issue of allocation has been addressed by a large number of researchers and experts. Location theories focused on searching a general model of optimal location of one or more companies began to emerge at the end of the 19th century.

There are four generations of location theories. The first location theory, also known as Von Thünen's model of land use, considered the costs of localization of agricultural products. According to Von Thünen, the distance between the land used and the market is an important factor.

According to his model, the gross cost of the product (ki) is given by the production costs (k), the distance between the site and the sales market (d) as well as specific transport costs (t). The cost of product at the point "i" can be determined as follows:

$$ki = k + tdi, \quad [\$] \quad (1)$$

- A. Weber dealt with the distance factor in the context of industrial companies' location, considering it a precondition for the second generation of location theories. It aims to find the ideal balance of transportation costs between the points of entry and exit. [3,13] The application of von Thünen's location model was addressed by several German authors, including W. Roscher, A.E.F. Schaffle, and W. Launhardt.

2.1 Weber's Location Model

German economist A. Weber built on the Launhardt model, which assumes the existence of two production factors located at different places and is based on minimizing the transportation costs of the company. Weber's location triangle is modified by a new factor. In terms of location, companies consider not only transportation costs as a function of distance but also the importance of the weight

and volume of materials and goods [4,13]. Basically, it is about finding a solution to the problem shown in Figure 2.

Fig. 2 Location of the object O. Source: [4]

There are given places of consumption A_i , where their position is determined by the coordinates (x_i, y_i) for $i = 1, 2, \dots, n$. Then we find object O with coordinates (x, y) for which the sum of distances from all places of consumption is minimal. The distance from point A_i to point O is expressed by the following formula:

$$\overline{A_i O} = \sqrt{(x_i - x)^2 + (y_i - y)^2} \quad (2)$$

At this point, it is necessary to determine the limit of point O (x, y) , for which the sum of distances between the places of consumption and the point O is minimal. To solve the transport problems in the deployed model, it needs to be extended by assigning certain importance weight " v_i " to each relocation source that corresponds to the scope of the relocation relationships

$$\sum_{v_i}^n v_i \sqrt{(x_i - x)^2 + (y_i - y)^2} \rightarrow \text{minimum} \quad (3)$$

Where in formulas 2 and 3:

x_i, y_i ... coordinates of point A_i in coordinate system

x, y ... coordinates of point O (object) in coordinate system

v_i ... importance weight of the scope of relocation relationships [4]

In the 1950s, French school of spatial economics was established in France. Its main representative is F. Perroux, who developed the growth pole theory. Its main idea is that economic development, or growth, is not uniform within an entire region, but instead, it is concentrated around a specific pole. Such a pole is often characterized by key industries around which linked industries develop, mainly through direct and indirect effects. At the turn of the 19th and 20th centuries, A. Marshall influenced the development of localization theories and examined selected characteristics of industrial production. One of these functions is the inertia of the industry in the given place. [5,11,12]

Marshall's theory was further developed by G. Becattini, who formulated the concept of industrial districts in the late 1970s. Marshall claims that if an industry chooses a locality for itself, it is very likely that it will stay there for a long time.

This can be defined as an area in which small and medium-sized companies producing goods or providing services are associated with the main production activity. [6]

His theory was extended by M.A. Porter and M. Enringthom in the 1990s, who created a new theory, so-called cluster theory. The theory states that concentrating industries in specific regions has several advantages. First, there is little competition, which means higher profits for firms. Steady presence of a stable customer base guarantees their business a steady income. Steady presence of suppliers means low costs for the firms as well. Geographic concentration also enables the creation of more personal relations that provide better business results in every sense. [7,9,10]

3. Analysis of Particular Company Distribution

For the purposes of the analysis, example of a Slovak company distributing products at regular weekly intervals on Fridays and Saturdays. The production hall of the company is situated in Spišská Nová Ves, a town in the east of Slovakia. Based on the company's internal data, the period of September 2017 – December 2018 was analysed. Within this period, the products were supplied to 28 regular customers (out of a total of 49 customers) were provided. The list of all regular customers with the specified location is presented in Table 1. They were also allocated importance weight based on the number of product purchased. The locations are shown in Figure 3.

Table 1 Sales to regular customers based on the distribution place. Source: authors

Customer location	Latitude	Longitude	Importance weight
A_i	x_i	y_i	v_i
Banska Bystrica	48.736277	19.1461917	144
Bratislava	48.1485965	17.1077477	25 193
Brezno	48.8060729	19.6438177	310
Dobra Voda	48.5973319	17.5385072	9768
Dunajska Streda	47.9916348	17.6206306	312
Ivanka pri Dunaji	48.1897372	17.2557153	784
Kosice	48.7163857	21.2610746	1 288
Lucenec	48.3286673	19.6690601	192
Malacky	48.4363404	17.0182641	768
Martin	49.0616613	18.9190235	250
Nitra	48.3061414	18.0763759	2 760
Nove Zamky	47.9881643	18.1571098	96
Partizanske	48.628493	18.3768911	240
Piestany	48.5917973	17.8271549	720
Podunajske Biskupice	48.1251057	17.2107902	72

Poprad	49.0511221	20.2954139	168
Povazska Bystrica	49.1131198	18.447663	336
Ruzomberok	49.0752393	19.3066002	168
Senec	48.2170352	17.4061427	174
Stara Lesna	49.1361539	20.3064689	72
Stupava	48.2749212	17.0318863	912
Svaty Jur	48.2543374	17.2119074	1 108
Topolcany	48.5589454	18.1700065	120
Trencianske Teplice	48.9094889	18.1675364	120
Trencin	48.884936	18.0335208	720
Trnava	48.3709108	17.5833218	1 397
Zvolen	48.5761806	19.1371155	1 024
Zdiar	49.2713457	20.2734093	120
Zilina	49.2194498	18.7408001	656

Fig. 3 Location of regular customers in Slovakia. Source: [8]

To be able to propose a new distribution site location, it is necessary to specify the geographical location of Slovakia. The area of exploration is given by the geographical coordinates of the southernmost, northernmost, westernmost, and easternmost inhabited places in Slovakia. Individual locations and their coordinates are shown in Table 2 and Figure 4.

Table 2 Geographical location of Slovakia. Source: [8]

	Place	Latitude	Longitude
southernmost	Patince	47.738304	18.289374
northernmost	Oravská Polhora	49.544669	19.373745
westernmost	Záhorská Ves	48.264398	16.957896
easternmost	Nová Sedlica	49.048250	22.515080

Fig. 4 Regular customers' locations in the geographic coordinate system. Source: authors

Based on Weber's location-allocation model, Table 3 shows the value of 30459.26501 (marked red), which represents the minimum distance from all customers. The calculated coordinates for the location of distribution site are 48.34069233 (latitude) and 17.57536089 (longitude). The distribution site is located in western Slovakia near Trnava. It is an expected result, as three of the company's largest customers are also located in western Slovakia. The geographical location of the distribution site is shown in Figure 5.

Table 3 Resulting matrix of Weber's location-allocation model. Source: authors

	16,957896	17,57536089	18,19282578	18,81029067	19,42775556	20,04522044	20,66268533	21,28015022	21,89761511	22,51508
49,544669	74587,16533	70188,97236	77978,17484	94618,42408	116709,8028	141763,0132	168607,4351	196713,1753	225823,4124	255541,1574
49,3440062	66064,24174	61299,989	70339,58453	88451,30052	111810,18	137747,7254	165207,2267	193752,3437	223286,6846	253343,5642
49,1433434	57894,74132	52693,27866	63385,32515	83155,42151	107662,5203	134420,0449	162403,3025	191274,1355	221200,3604	251548,1059
48,9426807	50234,12505	44497,68253	57407,26432	78997,90366	104395,9475	131858,3214	160251,9851	189296,9071	219592,8275	250167,8051
48,7420179	43319,04484	36940,14628	52840,03238	76012,58049	102115,492	130107,1969	158793,253	187839,9147	218492,974	249212,7011
48,5413551	37457,44739	31508,57756	49974,01495	74335,69961	100913,0337	129183,6583	158044,3324	187340,9467	217918,1539	248688,537
48,3406923	33203,35515	30459,26501	49097,84848	74065,76709	100809,9598	129087,4677	157996,1652	187437,4183	217863,3117	248596,0807
48,1400296	32488,31642	32356,36421	50609,96253	75164,05204	101739,2701	129802,6298	158621,0163	188055,283	218308,0828	248931,4899
47,9393668	37844,51253	37002,09967	54014,35874	77527,11578	103614,6945	131293,1859	159886,9107	189187,4923	219230,3502	249687,4586
47,738704	45588,23474	43766,30095	58851,34986	81022,7436	106362,2687	133513,2606	161762,781	190823,4931	220611,262	250854,4865

Fig. 5 Proposed location of the distribution site. Source: [7]

To obtain a more accurate location of the distribution site, the calculation needs to be repeated according to Weber's model. The area in which the distribution site location is sought can be narrowed by changing the geographic coordinates of the location area to specify the location of the distribution site.

4. Discussion

The main objective of this paper was to determine the optimal location for a new distribution site using Weber's location-allocation model. Based on theoretical findings in professional literature, empirical interviews, and observation, it can be concluded that determining the right location for a new distribution site location is a complex process that requires a huge amount of diverse information. For the purposes of the contribution, distribution site location was selected on the basis of the location of regular customers. Since a new distribution site is proposed, it was necessary to consider the transport distance to customers. If other values or characteristics of the distribution concept were considered, the calculation model would need to be changed as well. Further research in this field could be focused on whether it is better to use outsourcing or own vehicles for product distribution.

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