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Potential of Commercial Warehouse Space in Poland

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Abstract:
Warehousing is one of the main areas of cost optimization for companies. Investing in renting warehouse space gives companies great flexibility, allowing them to adapt to changing needs by choosing the type and location of the facility based on current requirements. Warehousing can bring important benefits to companies, such as increased efficiency, cost savings, and improved customer service. Commercial warehouse facilities play a key role in ensuring the smooth flow of goods and materials throughout the supply chain, from suppliers to customers. The warehouse space segment in Poland is new compared to Western European countries. Nevertheless, thanks to convenient geographic conditions, increasingly better road infrastructure, and growing demand for warehouse space and access to skilled labor force, its development is gaining momentum. This leads to an increasingly competitive Polish warehouse market in Europe. The purpose of the survey was to determine the potential of warehousing in Poland. A total of 459 characterizations of commercial warehouse space were collected to estimate the available and future warehouse space, its structure, and available equipment. Based on the results obtained, a ranking of optimal combinations of variables was indicated, which best illustrates the potential of commercial warehouse space not only on a national scale but also on the scale of international logistics activities, which can be considered an innovative approach to the examined issue. The analyses were performed using basic indicators of descriptive statistics and the linear ordering procedure.

Keywords: warehouse space market, warehouses, Poland.

波兰商业仓库空间的潜力

摘要：
仓储是企业成本优化的主要领域之一。投资租赁仓库空间为企业提供了极大的灵活性，使他们能够根据当前需求选择设施的类型和位置，以适应不断变化的需求。仓储可以为企业带来重要的好处，例如提高效率、节省成本和改善客户服务。商业仓库设施在确保整个供应链中货物和材料的顺畅流动（从供应商到客户）方面发挥着关键作用。与西欧国家相比，波兰的仓库空间领域尚属新兴领域。然而，由于便利的地理条

件、日益完善的道路基础设施以及对仓库空间和熟练劳动力的不断增长的需求，其发展势头强劲。这导致波兰仓库市场在欧洲的竞争日益激烈。调查的目的是确定波兰仓储的潜力。共收集了459个商业仓库空间特征，以估计可用和未来的仓库空间、其结构和可用设备。根据所得结果，对变量的最佳组合进行了排序，这最能说明商业仓库空间不仅在国家范围内而且在国际物流活动范围内的潜力，这可以被视为对所研究问题的一种创新方法。分析是使用描述统计的基本指标和线性排序程序进行的。

关键词：仓库空间市场，仓库，波兰。

1. Introduction

Over the past decade or so, most companies have experienced rapid changes caused mainly by external factors. The intense development of technology, ubiquitous globalization, changing customer trends, and their growing expectations have forced many companies to make new strategic operational decisions. In addition, the past few years have brought many unexpected crises, such as the COVID-19 pandemic and the war in Ukraine. Because of the rapid changes, businesses must find new solutions to overcome emerging challenges.

Warehousing is one of the main areas of cost optimization for enterprises. According to the literature, 23% of logistics costs in the United States and 39% in Europe are attributable to warehousing activities (Fumi et al., 2013). Investment in renting warehouse space allows companies high mobility due to the ability to choose the type and location of the facility, depending on the needs at a given time, the possibility of using modern technological and personnel facilities, and the minimization of formal aspects required for owning one's warehouse (Correia & Melo, 2022; Hrušecká et al., 2018). Warehousing provides companies with several important benefits, including increased productivity, cost savings, and improved customer service. Commercial warehouse facilities play several key roles in ensuring the smooth flow of goods and materials throughout the supply chain, from suppliers to customers.

The warehouse space market in Poland is young compared to Western European countries. However, due to excellent geographical conditions, increasingly better road infrastructure, growing demand for warehouse space, or the availability of qualified labor, its development is dynamic. This has made the Polish warehouse space market increasingly competitive on a European scale. Poland has one of the largest rental shares in total demand (about 13%), followed by Germany (24%) (Rzeczpospolita, 2023). However, the ever-increasing demand for warehouse space means that the availability of such space also should increase.

Identifying and understanding issues in the Polish warehouse space market can be a key tool for entrepreneurs, investors, and politicians who want to make better use of development opportunities in the country's warehouse sector. Therefore, the aim of this research was to identify the storage potential of warehouse facilities in Poland.

2. Literature Review

2.1. Concept and Types of Storage Space

Warehousing is an important part of the supply chain and any manufacturing facility as it allows a company to manage fluctuations in market demand (Ghalehkhondabi & Masel, 2018; Staudt et al., 2015). The term warehouse colloquially means "a type of real estate, usually considered as a building designed to store various types of goods" (Budner, 2020). An expanded definition of warehouses was proposed by Coyle et al. (2010): "A warehouse is a place in a logistics system where an enterprise stores or accumulates raw materials, semi-finished or finished goods at different times." In explaining the concept of warehouses, Januła et al. (2020) focused on the essence of these facilities in the logistics process: "the warehouse is the basic element of logistics infrastructure in any enterprise. It is also the keystone connecting the basic phases of material turnover, by which we mean buying and selling in a commercial enterprise and buying and selling in a manufacturing enterprise." Typically, warehouses are systematized according to several distinguished categories (Chudzik, 2018):

- Functions;
- Product types;
- Locations;
- Degree of mechanization;
- The storage and loading methods.

The storage and distribution of goods are the services provided by warehouses and are most often mentioned in the cited definitions (Octaviani, 2022). However, warehouse structures in terms of logistics facilities can also provide other various services, such as picking, assembling, packing, and labeling products (Kao et al., 2018; Tang et al., 2021; Kłodawski et al., 2017; ten Hompel & Schmidt, 2008). Another of the primary functions of a warehouse is to provide a safe, controlled environment for the storage and movement of goods. To this end, these facilities are equipped with a variety of facilities and machinery, such as forklifts, loading docks, conveyor belts, shelving, and racks, to facilitate efficient product movement, sorting, and distribution (Tien et al., 2019; Eko Saputro & Daneshvar Rouyendegh, 2016; Kmiecik, 2023). Warehouses can also provide temperature and humidity control, security systems (CCTV), fire sprinklers, smoke dampers, and railroad sidings. Warehouse structures are built on a range of sizes, from a few square meters to several hundred thousand square

meters, depending on the needs of the users. The requirements dictated by landlords and owners largely justify the location of these facilities; they can be situated in either urban or rural settings and found in areas with varying degrees of population density. However, warehouses are often built near road transport hubs, seaports, river ports, airports, and railroad stations.

Companies and other individuals who are customers using these facilities often require a wider range of logistics processes provided by warehouse facilities. These more advanced requirements can be met by logistics and distribution centers. According to one definition, a logistics center is "the hub of a specific area where all the activities relating to transportation, logistics, and goods distribution—both for national and international transit—are carried out on a commercial basis by various operators" (Ulutaş et al., 2020). A logistics center is perceived as an "integrator" of various transport modes and can promote intermodal transport. It is mainly an intermodal terminal, where the transhipment of goods from one mode to another occurs (Erkayman et al., 2011). A distribution center is a business unit or organizational unit within an enterprise or group of entities that has the appropriate logistics infrastructure, along with the means of operation and information flow required for the comprehensive provision of logistics services. These services include warehousing, order picking, shipment of goods, and various additional logistics activities necessary to fully satisfy customer needs (Śliwczyński & Koliński, 2014). Logistics and distribution centers are considered key components of economic development in a region, contributing to the development of advanced logistics networks. At the same time, both the creation and improvement of such facilities are highly dependent on the location of the region in which they are operated (Grondys & Dragolea, 2016).

2.2. Role of Warehouse Space in Logistics

Every year, the needs and requirements of both individual customers and existing and start-up companies grow and evolve in line with changing trends. This process significantly affects logistics facilities; initially, warehouses were used only for storing goods. Their role has evolved to become efficiently managed facilities that can be part of a company or independent units providing services to other companies. The organizational and logistical aspects of warehouse management are the fulcrum of an enterprise's management system, and warehouse management should be considered one of the most important components of the logistics sphere, with effectively managed warehouse processes positively influencing the efficient flow of goods from suppliers to customers (Rut & Kulińska, 2011; ten Hompel & Schmidt, 2008). Warehouses are a fundamental link in the supply chain (Ramaa et al., 2012).

Fertsch (2007) stated that the role of the warehouse is to meet fundamental logistics needs by coordinating demand and supply according to circumstances, minimizing the cost of receiving and storing goods and their scarcity, and assisting in production and marketing activities. In addition, the optimal management of warehouse space makes it possible to minimize the costs associated with the maintenance of goods. A special role in this aspect is played by logistics centers, which, due to their access to technical and logistical infrastructure and appropriate means of transport and the guarantee of providing the required conditions for storing goods, improve the efficiency of distribution channels in the supply chain (Budner & Pawlicka, 2020; Singh et al., 2018). The benefits of renting warehouse space at a logistics center include optimizing inventory and distribution processes, reducing lead times, increasing transportation efficiency, optimizing costs, improving product quality control, and adjusting the amount of inventory to market demand.

2.3. European Warehouse Space Market

The growth of the e-commerce market has put increasing pressure on various links in the supply chain, including warehouses and distribution and logistics centers, which have played an important role in optimizing distribution processes (Nong, 2022). Until a certain point, countries such as the Netherlands, the United Kingdom, and Germany were the centers of logistics activities. However, new markets in the Central and Eastern European (CEE) region are increasingly attractive to warehouse investors. One of them is Poland for several important reasons. First, its strategic location in Central Europe makes it an excellent transit point for transporting goods to both the east and west of the continent. Second, its developed road networks, including highways and expressways, facilitate efficient distribution of goods both within the country and internationally. Third, the stable economic and political situation makes investors confident about long-term business prospects. In addition, the cost of doing business in Poland, including labor and real estate costs, is competitive with that in other European countries, which attracts investors looking for efficient logistics solutions. According to a report by a real estate consultancy Savills (2023), despite the high cost of investment financing and increasing rental costs, demand for warehouse leasing in Poland in 2022 was characterized by a high growth rate. At that time, nearly 7 million m2 of warehouse space was leased, one of the highest figures in the Polish warehouse market.

CRBE's projections of a $1.5-trillion (€1.3-trillion) increase in global e-commerce sales over the next five years will require an additional 140 million m2 of space worldwide, with 27 million m2 needed in Europe (Dexion, 2021). Recent forecasts predict that new space construction can be limited to as little as 3 million m2. At the same time, the vacancy rate at the end of 2022 was only about 4%, lower than in previous years (Savills, 2023). Strong demand for warehouses, remodeling of supply chains, continued strong tenant demand, and limited supply due to declining land

availability mean that space rental opportunities are shrinking significantly. As a result, different European countries are at different stages of planning and implementing strategies to increase warehouse capacity and adopting different approaches.

3. Methodology

The purpose of this study was to determine the potential for warehouse space in Poland. The research was conducted using listings from www.magazyny.pl to identify warehouse space available for different types of buyers in the commercial market. Data were collected as of March 1, 2023, characterizing 459 commercial warehouse spaces, which allowed estimating available and future warehouse space, its structure, and available equipment. The warehouses surveyed were divided into three groups:

I. Group A included entities categorized as logistics centers; due to the discrepancy between the definitional treatment and the terms "logistics center" appearing in the names of the entities or in the descriptions of the space rental offers, identifying these entities was difficult. However, it was considered that since the defining feature of a logistics center is the ability to integrate at least two modes of transportation, entities with rail sidings located in them, as well as those located on or near airports and seaports, were included in this group.

II. Group B included units designated as distribution centers and those originally identified as "logistics centers" in unit names or descriptions of space lease offers because the scope of functions in both types of entities (aside from the requirement to integrate at least two modes of transportation) was almost the same.

III. Group C, on the other hand, includes all other warehouse spaces, i.e., logistics parks, warehouses, and offices.

Based on the obtained data, it was observed that the largest amount of space available in Poland is classified as distribution centers (group B in the survey). They occupy 52.9% (243 facilities) of the total number of warehouse facilities surveyed. This was followed by a fairly large group of units belonging to group C, which included warehouses, offices, and logistics parks (41.2% - 189 facilities). The least numerous facilities were logistics centers, which in group A occupied 5.9% (27 facilities) of all surveyed warehouse space in the country.

To assess the storage potential, the empirical part was divided into three stages:

1. The stage of identifying and evaluating the basic parameters of storage facilities;
2. Modeling the optimal potential of storage space;
3. Determining the potential of commercial warehouse space.

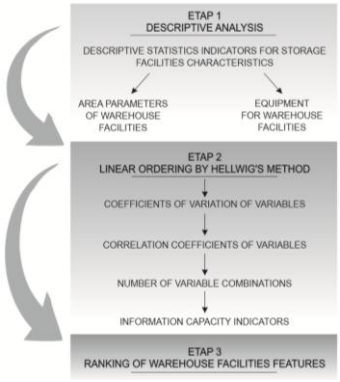

Figure 1. Research methodology (Developed by the author)

The implementation of Stage 1 included the identification and analysis of the main characteristics of the storage facility. Based on the available information, the basic indicators of descriptive statistics were estimated. At Stage 2, the linear ordering procedure was carried out according to the following steps (Bąk, 2018):

• "Defining the nature of the variables;
• Determining variable weights and their normalization;
• Determining pattern coordinates in the case of pattern aggregation;
• Model-free or benchmark aggregation."

To analyze the data, a model-free method was selected, namely a principal component analysis based on the values and eigenvectors of the covariance or correlation matrix. Based on the results, in the third stage, a ranking of optimal combinations of variables is indicated, which best shows the potential of commercial warehouse space in Poland, depending on the surface parameters and equipment of the warehouse facility.

4. Results

4.1. Assessing Storage Potential Based on Space and Equipment Parameters

To assess the available potential of the storage space, its basic parameters were analyzed. Table 1 presents the general characteristics of the studied facilities according to the type and size of space.

Table 1. Characteristics of general warehouse space parameters in Poland (Developed by the author)

Storage space type	Target storage space [thousand m^2]		Existing space [thousand m^2]		Available space under construction [thousand m^2]		Expandability [thousand m^2]		Number of buildings [pcs.]	
	Total	Average	Total	Average	Total	Average	Total	Average	Total	Average
CL	2192.3	81.2	69.5	8.69	20.2	6.7	471.1	52.3	101	3.74
CD	17027.7	70.7	800.1	4.79	661.8	2.83	4801.9	27.91	628	2.58
Other	10963	58.0	440	3.16	517	3.1	3715	30.9	468	2.5
Total	30 183		1 309.6		1 199		8 988		1 197	

* The average was calculated as the quotient of the storage area in each of the indicated groups and the number of units included in them (Table 2).

In total, domestic warehouses currently have more than 1.3 million m^2 of leasable space, of which the volume of space available under construction is almost 1.2 million m^2, while the target warehouse space is expected to reach more than 30 million m^2. Both existing space and that under construction each occupies approximately 4% of the target warehouse space. At the same time, the possibility of expansion is shaping up at a total of more than 8.9 million m^2. In total, the country's warehousing space has almost 1,200 buildings, with the largest number (628) located in distribution centers. The largest target and existing space is held by distribution centers, other warehouse space, and logistics centers, respectively. Analyzing the average warehouse space in each category, logistics centers have the largest available existing space (8,690 m^2). Similarly, for the other categories, the highest average values are also recorded for logistics centers: available space under construction: 6,700 m^2; expandability: 52,300 m^2; target warehouse space: 81,200 m^2. Although the number of logistics centers accounted for the smallest share in the entire surveyed population, they had a larger number of buildings on average (3.74) than distribution centers and other warehouses. The averages obtained for each category may indicate that developers realize the attractiveness of typical logistics centers, which allow for a wider range of feasible transportation processes, and try to offer as much space as possible for lease in these units. However, it should be borne in mind that their small size is determined by the possibilities of combining the infrastructure available in Poland for various modes of transportation.

An interesting picture of domestic warehouse space emerges when the availability or created warehouse space is considered (Table 2).

Table 2. Available and created storage space (Developed by the author)

Storage space type	Existing space		Available space under construction		Expandability	
	Number	%	Number	%	Number	%
CL	8	2.5	3	0.75	9	3
CD	169	53.5	234	58.2	172	57.1
Other	139	44	165	41.05	120	39.9
Total	316	100	402	100	301	100
Share of the total number of facilities	69%		88%		66%	

Nearly 70% of the facilities among the entire surveyed population have no available space, while to meet the existing market demand, 88% of all warehouses are in the process of building new facilities for maximum available space. Nearly 2/3 of the warehouse space still has room for expansion.

An important factor determining the country's storage potential is the equipment of the surveyed facilities. The most important installations and equipment that influence the customer's choice of warehouse are highlighted here. To ensure safety, fire sprinklers, smoke dampers, and CCTV video surveillance systems are installed. To improve logistics processes, cross-docking activity areas and railroad sidings are constructed. Some of the available warehouse space can be used for manufacturing processes. Manufactures that do not require the warehouse to be adapted for production processes can use the ready-made solutions available in the offered light manufacturing space. Table 3 shows the number of facilities according to the type of warehouse equipment.

Table 3. Number of storage facilities by equipment type (Developed by the author)

Storage space type	Sprinklers (pcs.)	Cross-dock [pcs.]	Smoke dampers [pcs.]	CCTV [pcs.]	Rail siding [pcs.]	Light production [pcs.]
CL	95	14	97	73	10	86
CD	150	85	148	143	0	143
Other	145	47	152	128	0	137
Total* [pcs.]	390	146	397	335	10	366
Share of total number of entities	85%	32%	86%	73%	2%	80%

* For 33 entities, no equipment data are available.

Not all facilities have full warehouse equipment. Based on the number of warehouses, most have fire sprinklers (85%), smoke dampers (86%), CCTV monitoring (73%), and light manufacturing equipment (80%). One of the three warehouses also has a cross-dock mechanism (32%). At the same time, only 2% of the surveyed facilities have access to railroad sidings. This means that only a limited number of facilities in Poland's warehouses are suitable for bimodal transportation. Table 4 shows the quantitative equipment level by facility type.

Table 4. Available and created storage space (Developed by the author)

Variables	Arithmetic	Standard	Coefficient of
	average $\bar{x}$	deviations	variation V [%]
x_1	65823	73156	>100
x_2	2853	6954	>100
x_3	2628	9447	>100
x_4	19628	50905	>100
x_5	2.1	2.63	94
x_6	2.55	2.53	99
x_7	0.67	1.40	>100
x_8	2.58	2.54	99
x_9	2.01	2.36	>100
x_{10}	0.05	0.35	>100
x_{11}	2.32	2.53	>100

4.2. Modeling the Optimal Storage Space Potential

Based on the findings from the first stage of the study, potential variables for commercial warehouse space study were determined: target park space (x_1),

available space (x_2), available space under construction (x_3), expansion potential (x_4), number of buildings (x_5), sprinklers (x_6), cross-dock (x_7), smoke dampers (x_8), CCTV (x_9), rail siding (x_{10}), and light manufacturing (x_{11}).

In the process of modeling the optimal potential, a procedure was used that included determining the nature of the variables using the linear ordering method. For this purpose, we checked the variability of each variable according to the following formula (Ręklewski, 2020):

$$V = \frac{s}{\bar{\bar{x}}}$$

The results of the coefficient of variation are presented in Table 4.

Each of the analyzed variables had a strong and very strong variation of V > 90%, which is the condition for linear ordering. This means that at this stage, all variables are further analyzed. The second important condition was to remove highly correlated data from the analysis or reduce them (Table 5).

Table 5. Correlation results for the explanatory variables (Developed by the author)

	x_1	x_2	x_3	x_4	x_5	x_7	x_9	x_{10}	x_{11}
x_1	1	.283**	0.071	0.716**	0.684**	0.542**	0.563**	0.231**	0.694**
x_2	0.283**	1	-0.023	0.025	0.215**	0.135**	0.131**	0.083	0.188**
x_3	0.071	-0.023	1	-0.026	-0.037	-0.080	0.012	-0.037	-0.033
x_4	0.716**	0.025	-0.026	1	0.315**	0.254**	0.306**	-0.009	0.331**
x_6	0.702**	0.192**	-0.016	0.322**	0.904**	0.494**	0.833**	0.223**	0.922**
x_7	0.542**	0.135**	-0.080	0.254**	0.468**	1	0.274**	0.036	0.487**
x_8	0.688**	0.178**	-0.047	0.316**	0.937**	0.489**	0.810**	0.223**	0.919**
x_9	0.563**	0.131**	0.012	0.306**	0.765**	0.274**	1	0.211**	0.784**
x_{10}	0.231**	0.083	-0.037	-0.009	0.212**	0.036	0.211**	1	0.225**
x_{11}	0.694**	0.188**	-0.033	0.331**	0.859**	0.487**	0.784**	0.225**	1

The strongest correlations for r* > |rij =0.5| are for variable x_1 with variables x_4, x_5, x_6, x_7, x_8, x_9, and x_{11}. Other variables, i.e., x_2, x_3, and x_{10}, correlate weakly with other variables. Because of the value of the correlation coefficient, x_4, x_5, x_6, x_7, x_8, x_9, and x_{11} are removed from the set of variables.

In the end, four variables were left in further analysis, based on which a model was created for the optimal selection of warehouse space based on certain conditions.

The maximum sum of the selected variables (i.e., target storage space, existing storage space, storage space under construction, and number of rail sidings) was identified as storage potential (*y*). For each variable, the weight was identical at 25%. At the same time, due to the different methods of measuring the variables, to sum up their individual values, normalization was carried out using the standardization method. The linear ordering model was implemented using Hellwig's method, which was employed to ascertain the hierarchy of the objects under study (Łogwiniuk, 2011). The calculations began by determining the number of combinations of variables to be included in the model. The number of combinations of explanatory variables was estimated using the following formula (Jarocka, 2015):

$$S = 2^n = 2^4 = 16,$$

where *n* is the number of explanatory variables.

To indicate all possible combinations, a zero-one table was developed, where variables entering a given combination are written as 1 and those not entering a combination as 0. The zero-one combination matrix is presented in Table 6. One-element, two-element, three-element, and four-element combinations were considered sequentially. The number of combinations without repetition was calculated using Newton's formula (Centralna Komisja Egzaminacyjna, 2015):

$$\binom{n}{k} = \frac{n!}{k!\,(n-k)!}$$

Table 6. Zero-one combination matrix (Developed by the author)

Comb. no.	X_1	X_2	X_3	X_{10}	Variables in combination
1	1	0	0	0	x_1
2	0	1	0	0	x_2
3	0	0	1	0	x_3
4	0	0	0	1	x_{10}
5	1	1	0	0	x_1,x_2
6	1	0	1	0	x_1,x_3
7	1	0	0	1	x_1,x_{10}
8	0	1	1	0	x_2,x_3
10	0	1	0	1	x_2,x_{10}
11	0	0	1	1	x_3,x_{10}
12	1	1	1	0	x_1,x_2,x_3
13	1	1	0	1	x_1,x_2,x_{10}
14	1	0	1	1	x_1,x_3,x_{10}
15	0	1	1	1	x_2,x_3,x_{10}
16	1	1	1	1	x_1,x_2,x_3,x_{10}

Then, within each combination counted (Bąk, 2018):

1. Individual information capacity indicators (*hij*):

$$h_{s_j} = \frac{r_j^2}{\sum_{i \in c} |r_{ij}|}$$

2. Integral capacity indicators (*Hj*):

$$H_s = \sum_{i \in C_s} h_{s_j}$$

First, a correlation matrix was determined to form the basis for estimating the information capacity indicators (Table 7).

Table 7. Correlation coefficients between the studied variables (Developed by the author)

	Y	**X_1**	**X_2**	**X_3**	**X_{10}**
Y	1	-.092*	-0.034	-.154**	0.074
X_1	-.092*	1	-.125**	-0.081	-0.093
X_2	-0.034	-.125**	1	0.061	0.050
X_3	-.154**	-0.081	0.061	1	0.022
X_{10}	0.074	-0.093	0.050	0.022	1

The results for both types of indicators are included in Table 8, where the individual indicators of information capacity are located at the locations of variable combinations (at Location 1 according to the zero-one matrix), while the integral indicators of integration capacity are the sum of the individual indicators of each combination.

Table 8. Information and integration capacity indices of all combinations (Developed by the author)

Comb. no.	**X_1**	**X_2**	**X_3**	**X_{10}**	**H**
1	0.989	0.000	0.000	0.000	0.989
2	0.000	0.453	0.000	0.000	0.453
3	0.000	0.000	1.549	0.000	1.549
4	0.000	0.000	0.000	1.320	1.320
5	0.769	0.200	0.000	0.000	0.969
6	0.923	0.000	0.169	0.000	1.092
7	0.802	0.000	0.000	0.190	0.992
8	0.000	0.418	0.383	0.000	0.802
10	0.000	0.350	0.000	0.184	0.534
11	0.000	0.000	0.595	0.408	1.004
12	0.728	0.193	0.127	0.000	1.048
13	0.651	0.177	0.000	0.101	0.928
14	0.758	0.000	0.144	0.144	1.046
15	0.000	0.329	0.274	0.140	0.744
16	0.621	0.171	0.112	0.086	0.991

The H-index with the maximum value is responsible for the most optimal combination. Ordered in descending order integral information carriers (Table 9) allowed us to order combinations of variables.

Table 9. Integration capacity index rankings for all combinations (Developed by the author)

Combination number	**Variables in combination**	**Integration capacity index**
3	x_3	1.549
4	x_{10}	1.320
6	x_1,x_3	1.092
12	x_1,x_2,x_3	1.048
14	x_1,x_3,x_{10}	1.046
11	x_3,x_{10}	1.004
7	x_1,x_{10}	0.992
16	x_1,x_2,x_3,x_{10}	0.991
1	x_1	0.989
5	x_1,x_2	0.969
13	x_1,x_2,x_{10}	0.928
8	x_2,x_3	0.802
15	x_2,x_3,x_{10}	0.744
10	x_2,x_{10}	0.534
2	x_2	0.453

The optimal set of variables is the one-element combination, number 3, which has only one variable, x_3 (available space under construction). This combination provides the best explanation of storage potential. Alternatively, the second best combination is also the one-element combination, number 4, which has variable x_{10} (rail siding). However, given that a model with only one variable is too unrepresentative, i.e., carries little information about the explanatory variable, at least a two-element combination is considered optimal. In this case, it is ranked by the value of H6 = 1.092, which applies to combination No. 6 and has two variables: x_1 and x_3. Therefore, the optimal combination of warehouse space features is the target park area and the available space under construction. These factors may constitute a competitive advantage in the warehouse space market.

5. Conclusion

The challenges of modern logistics—trends in the logistics market—put significant pressure on logistics operators, whose warehouse facilities are now expected to "flexibly" respond to changes in the environment (Miklinska, 2020). The high demand for warehouse space is driven by both the need to diversify the logistics network to suit the needs of the e-commerce market and the still existing congestion in global supply chains. The continuing trend of e-commerce impacts the warehouse market and how warehouses are built for tenants. Special attention is being paid to the problem of handling returns, which is also driving demand for warehouse space. In addition, the growth of e-commerce sales should accelerate the development of the "last mile" warehouse market. The demand for new warehouse space is also related to the need to increase the inventory or keep it constant. While supply chains seek to minimize inventory to reduce costs and prices of goods, it is increasingly important to maintain adequate inventory levels to maintain supply continuity under uncertain conditions. In the face of potential inventory shortages and revenue losses, resilience becomes more important than supply chain performance (Budner, 2023; Marcysiak, 2020).

The warehouse space market on a European scale shows that different countries are at different stages in the process of planning and implementing strategies to increase storage capacity and using different approaches. The Polish warehouse market is developing rapidly. The continuous influx of foreign investment, economic development, the emergence of new businesses, and the opening of more commercial facilities have triggered the need to expand the commercial offer of warehouse facilities. Nevertheless, distribution centers and other warehouse parks represent

the majority of these facilities. There are relatively few logistics centers in Poland. This is due to the omission of this issue from the state's transportation policy (Bocheński, 2018).

The identification and analysis of the Polish warehouse space covered three stages of the study. The first, based on the estimation of basic statistical indicators, showed that not all the opportunities available for commercial warehouse space in Poland have yet to be used. Furthermore, a considerable number of facilities are currently undergoing or have the potential for expansion. Concurrently, the availability of warehouse space is constrained, indicating a high rate of customer rental. Most facilities also have extensive equipment to secure customers' goods and facilitate storage processes. Stage 2 enabled the selection of the best combination of variables to optimally determine the potential of commercial warehouse space. Based on the results obtained, in the third stage, a ranking of optimal combinations of variables was indicated, and in selecting the optimal warehouse space, the target area of the warehouse park and the available space under construction proved to be the most important factors. These two factors are dominant in assessing the availability and level of use of warehouse facilities and can be applied to other countries to assess their warehouse potential. They determine both the current capacity to use external logistics infrastructure and its future trends.

The approaches proposed in this study effectively respond to the challenges and trends observed in the modern logistics market. The study emphasized the importance of warehouse facilities' features, which may be key to the flexible adaptation of logistics operators to the changing environment. The results also indicate the need to diversify space to meet the requirements of the e-commerce market. By expanding and optimizing the combination of features of warehouse facilities, logistics operators can improve order fulfillment, shorten delivery times, and improve customer service.

The recommendations derived from this study focus on the optimization of warehouse facilities and warehouse operations to meet the challenges and trends observed in the modern logistics market. It is recommended that warehouse space providers pay special attention to expanding available warehouse space and creating new facilities that are better connected to infrastructure enabling intermodal transport.

The research conducted has some limitations. In the context of selecting potential space for lease, only factors related to warehouse facilities and their equipment were considered, and the results of this study may be useful primarily to developers. The study did not include other variables, such as location or proximity to transportation infrastructure, because warehouse users would have to be involved in the study. At the same time, it provides a direction for exploring issues in the warehouse space market in Poland.

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