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SHAPING CROSS-DOCKING FACILITIES IN DAIRY SUPPLY CHAINS®

Kształtowanie obiektów typu cross-docking w łańcuchach dostaw branży mleczarskiej®

Key words: dairy industry, supply chain, cold chain, cross-docking, technical object, distribution logistics.

The article presents variants of shaping cross-docking facilities in which products from the dairy industry are served. Due to the type of goods, it is important to shorten the supply chain, as the products quickly turn sour or change consistency. The cross-docking method is defined as the distribution of goods, which eliminates the stage related to product storage in the supply chain. The goods go from suppliers to the facility, where they are properly consolidated and then directly shipped to a given recipient, in accordance with his order. The technical object aims to simplify the network of connections between them. Thanks to the cross-docking solution, it is possible to obtain shorter order fulfillment times and reduce the costs associated with the storage of goods. The use of appropriate technology in a cross-docking facility improves the flow of cargo, increases process safety and improves efficiency. Considering the dairy industry products, you should also pay attention to the rules and legal regulations that play a very important role in the transport of goods in order to maintain the cold chain.

Słowa kluczowe: branża mleczarska, łańcuch dostaw, łańcuch chłodniczy, cross-docking, obiekt techniczny, logistyka dystrybucji.

W artykule przedstawiono warianty kształtowania obiektów cross-dockingowych, w których obsługiwane są produkty z branży mleczarskiej. Ze względu na rodzaj towaru ważne jest skrócenie łańcucha dostaw, ponieważ produkty w niekontrolowanych warunach szybko kwaśnieją lub zmieniają konsystencję. Metoda cross-docking definiowana jest jako dystrybucja towaru, która eliminuje etap związany z magazynowaniem produktów w łańcuchu dostaw. Towar trafia od dostawców do obiektu, gdzie jest odpowiednio konsolidowany, a następnie bezpośrednio wysyłany do danego odbiorcy, zgodnie z jego zamówieniem. Obiekt techniczny ma na celu uproszczenie sieci połączeń między nimi. Dzięki rozwiązaniu cross-docking możliwe jest uzyskanie krótszych czasów realizacji zamówień oraz obniżenie kosztów związanych z magazynowaniem towaru. Zastosowanie odpowiedniej technologii w obiekcie cross-dockingowym poprawia przepływ ładunków, zwiększa bezpieczeństwo procesu i poprawia wydajność. Mając na uwadze produkty branży mleczarskiej należy również zwrócić uwagę na zasady i regulacje prawne, które odgrywają bardzo ważną rolę w transporcie towarów w celu utrzymania łańcucha chłodniczego.

INTRODUCTION

Supply chains should become more resistant to disruptions in the face of a dynamically changing market. To do this, they must be more intelligent, dynamic and equipped with the right information [27, 29]. However, recently there are many reasons why the supply chain has been in crisis. One example is the COVID-19 pandemic that started in March 2020. After the outbreak, a large number of factories suspended their production. As emphasized by the author [28], this resulted in a disproportion between supply and demand. There were delivery delays, logistical problems and restrictions related to international trade. In addition, global supply chains were shaken by Russia's invasion of Ukraine, which began in February 2022. According to [13] the main reasons for the disruptions were Ukraine's exclusion from transit and production problems. It should be emphasized that Ukraine is one of the four most important exporters of wheat in the world. The port blockade has resulted in the transport of grains to the most needy countries such as Ethiopia and Yemen.

The food industry is currently in a crisis. Many producers, in times of high prices of materials and raw materials, consider temporarily suspending production. It could also lead to a disruption of the supply chain and a shortage of products on store shelves [4]. On the other hand, there is a growing demand for products that are characterized by ever higher quality, are the freshest possible and available to the consumer at any

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time. Therefore, it forces a continuous shortening of supply chains. Cross-docking warehouses (transhipment terminals) stand in front of these requirements. The authors [2, 6] claim that these are facilities where the goods are picked up from the supplier and shipped directly to the recipient, skipping the warehousing stage. A properly shaped cross-docking facility shortens the time of handling goods, and thus the time of supply chain execution.

The authors [12, 19] emphasize that a cross-docking warehouse is irreplaceable where efficient transport of products in the shortest possible time is of key importance. Cross-docking devices are used when handling goods with a short shelf life or where fast delivery is important. The dairy industry seems to be susceptible to the implementation of the cross-docking concept. Modern warehouses with appropriately selected technology facilitate the handling of goods and simplify the network of connections in the supply chain, which is extremely important when reloading products from the dairy industry [33].

Supply chains are now evolving towards logistics systems that are more dynamic, more flexible, more customizable, more precise and more efficient. New digital technologies and automation are shaping a new concept of the supply chain. Elements that define the supply chain concept include, for example, the need to use technology to acquire and manage data. In the face of ever more voluminous and complex supply chains, information management has become an indispensable issue to be able to meet market demands. Another thing that is worth paying attention to is the greater integration of individual entities involved in the supply chain and process automation strategies to increase the precision and speed of execution. Effective supply chain management cannot be considered without taking into account the optimization of logistics processes of enterprises [3, 5, 30]. When transporting dairy products, it is very important to follow the rules of the „cold chain" terminology.

Taking into account the above, the authors divided the area of their work into 5 parts. The first part, which is in Chapter 2, provides an analysis of the literature on the legal regulations and rules that must be followed when transporting perishable goods. Chapter 3 presents the needs that contribute to the correct implementation of tasks in cross-docking technical facilities. The suppliers and recipients of the facility have been identified and the basic parameters determining the operation of the cross-docking facility have been described. The next Chapter 4 concerned the definition of design variants. Three variants of the object were presented. The next chapter dealt with the analysis of variants using the multi-criteria point method. The final part of the work presents a summary and conclusions are drawn from the research conducted in the field of shaping cross-docking facilities in the supply chain.

TRANSPORT AND STORAGE CONDITIONS FOR DAIRY PRODUCTS

Legal regulations concerning the transport of food and maintenance of the cold chain

The Polish legislator in the field of the transport of perishable products, including dairy products, derives its regulations from Community legal acts that have been implemented into the Polish legal system. The main act regulating the issue of transporting such means is the agreement on the international transport of perishable food products and on special means of transport for these transports (ATP) of September 1, 1970, which entered into force in Poland on May 15, 1984 (cf. U. 2015 item 667). Each carrier wishing to transport perishable foodstuffs is required to have a valid ATP certificate, which confirms that the means of transport meets the requirements of the ATP Agreement. The products of the dairy industry, as well as most of the perishable products, are susceptible to the development of microorganisms, e.g. bacteria and fungi, hence it is so important to observe the rules of transport hygiene and to maintain the efficiency of devices ensuring the control of the correct temperature of the transported products. In this regard, it is important that the products are transported at temperatures in accordance with the manufacturer's recommendation or the table contained in the ATP Agreement [1].

To maintain the freshness of dairy products and their desired quality, it is crucial to properly cool them and maintain a proper cold chain, because cooling is one of the most effective methods of extending the shelf life of the dairy industry [31]. By the cold chain, the authors [10, 26, 33] understand the proper organization of production, transport and storage in thermally controlled conditions, limiting the risk of product spoilage. The threats to the maintenance of the cold chain are, in particular, microbiological processes, physical changes and damage to the transported goods, chemical contamination and contamination, improper selection of the means of transport, packaging or containers, inadequate qualifications and training of the personnel, irregularities in the shipping documentation (in particular with regard to the desired temperature or type of transported food), damage to refrigeration equipment, which may also be caused by pests, i.e. rodents and insects [11].

Already at the production stage, it is important to ensure proper hygiene of both employees and production equipment, so that the product intended for the market meets the appropriate standards. For this purpose, modern dairy plants are equipped with systems monitoring the quality of products and their temperature. The response to the market requirements and the growing awareness of consumers is also the development of product packaging in the dairy industry [32]. A new trend on the market is the use of intelligent packaging equipped with an indicator that monitors specific parameters, including temperature - if the product reaches a temperature higher than recommended, the indicator permanently discolours to a certain color, thus informing the potential consumer that the product may have been stored at too high a temperature, which may translate into the quality and freshness of the product [15, 18].

Maintaining the cold chain is important because it affects the safety of the consumer who finally receives the product, so it is so important that the product is stored at the right temperature from the moment of production, as the authors [7, 24] claim. For the dairy industry, the temperature will most often be +6°C. As an exception, UHT sterilized milk can be stored under ambient conditions, ie approx. 25°C. Depending on the season, it will be necessary to either cool it down properly or warm it up properly so that the product does not freeze. However, short-term increases in storage and transport temperature by a maximum of 3°C, resulting from the undertaken technical activities necessary to perform the transport service, are permissible [33].

A critical point in maintaining the cold chain is the reloading of cooled products, e.g. from a refrigerated trailer to the warehouse. In order to reduce the undesirable risk of temperature rise, modern warehouses are equipped with insulated airlocks – the door of the vehicle's trailer during unloading is surrounded as tightly as possible by a lock isolating the air supply from the outside [9]. This allows you to protect the goods against uncontrolled and undesirable temperature rise, and also has a positive effect on hygiene in contact with food.

Decision support in shaping logistics facilities in supply chains

There are many publications relating to decision support in various areas. The authors [23] presented decision support in the case of container reloading services at an intermodal rail-road terminal. In another example, the authors [14] use fuzzy logic to support decisions in transport development planning. The authors [22] investigate the implementation of RFID in the supply chain. Among other things, in technical facilities. It is a very important element that can support the decision in shaping cross-docking facilities. It was the authors [16] who drew attention in their publication to the shaping of warehouse facilities.

Shaping cross-docking facilities should take into account, first of all, the purpose of the facility, which affects both the size and height of the building, the applied finishing standard and the internal transport solutions used. It is worth paying attention to the location and size of the plot. Much depends on the type of product to be stored in the hall. In the case of handling goods from the dairy industry, it is worth locating the technical facility as close to the collection points as possible. In this way, the product path is shortened, there is less likelihood of exposing the enterprise to loss [21, 25]. When it comes to products that are characterized by fast rotation, it is important to be close to the main communication routes.

Shaping cross-docking facilities requires the organization and distribution of appropriate work departments in different parts of the facility. When designing a facility, attention should be paid to a storage system that meets the required needs. They are: the best use of space, limiting the reloading of goods to a minimum, easy access to the stored product, the maximum possible rotation rate, maximum flexibility in product stacking and easy control of the number of stored goods. Technical requirements are important – if the type of stored products determines the need to maintain a constant temperature, this must be taken into account at the design stage.

The fast rotation of goods in the cross-docking facility means that it does not need to be equipped with racks, which in turn has an impact on the height of the hall. An ideal cross-dock facility is one in which as many docks as possible can appear in a small space. For such investments, the developer should provide additional equipment such as hydraulic ramps, ramps, bridges and comprehensive reloading systems. A maneuvering area of an appropriate size is also important, clearly larger than in the case of a standard logistics facility, as well as a large number of parking and parking spaces [16, 20].

DETERMINING THE NEEDS FOR THE IMPLEMENTATION OF TASKS IN CROSS-DOCKING TECHNICAL FACILITIES

Identification of suppliers and recipients

Goods from dairy cooperatives are delivered to the warehouse. The table 1 below lists the types of dairy products and specifies the requirements for their transport and storage.

Table 1. Storage and transport conditions for selected dairy products

Tabela 1. Warunki przechowywania i transportu wybranych produktów mlecznych

Product name	Storage and transport temperature
Butter	$\leq$ 6°C
Fresh dairy products	$\leq$ 6°C
Smoked cheese and yellow cheese	$\leq$ 10°C
Pasteurized milk	$\leq$ 6°C
UHT sterilized milk	$\leq$ 25°C

Source: The own study

Źródło: Opracowanie własne

The logistic task of the facility, generally speaking, is related to the determination of the type of cargo that is delivered to the warehouse. Illustrates the inlet and outlet flow rates. The logistics task shows the number of vendors and customers that are served by the warehouse. The term also defines data on 24 hours of deliveries and collections. Accordingly, identifying all the information provides the basis for designing a logistics system.

The cross-docking warehouse is located in central Poland. The location is convenient due to the elements related to the local labor market, i.e. the available workforce and its costs. An equally important factor is the vicinity of modern road infrastructure, as well as the main communication arteries. Considering the dairy industry goods handled by the warehouse, the quality of deliveries is very important. Suppliers cooperating with the warehouse are three dairies located in the Mazowieckie Voivodeship. The recipients are the ten branches of the self-service wholesalers' networks. Branches are scattered all over Poland [17].

Suppliers ship pallet units of homogeneous goods. The base is a EUR 1 pallet with dimensions of 1200 x 800 [mm]. Road transport is delivered by units in refrigerated semi-trailers, which have a capacity of 33 [units]. Transporting loads on a pallet involves the risk of damage during transport. The units are secured with foam corners. Layers of cardboard boxes or packs are interleaved with cardboard spacers. The stretch film is used to wrap the whole thing to strengthen the structure. Thanks to this, the goods are stabilized, which reduces the risk of damage to the parcels. The weight of the unit does not exceed 700 [kg], and the height does not exceed 1.4 [m].

Taking into account the goods from the dairy industry handled in the cross-docking warehouse, presented in tab. 1, it was assumed that the temperature inside the object is 6. At the transhipment terminal, both deliveries and shipments take place at night, which minimizes the inadequate influence of high temperatures. They are implemented evenly over their time windows. Goods are received at the cross-docking warehouse from 22:00 to 4:00. However, shipments of goods from the warehouse are carried out from 24:00 to 6:00.

Assumptions determining the work of the cross-docking facility

A warehouse facility that is to function rationally requires the presentation and definition of the values of all parameters that directly affect the warehouse process being carried out [17, 20]. The table below presents the basic parameters that were used to design a cross-docking warehouse.

Table 2. Parameters determining the work of the cross-docking warehouse

Tabela 2. Parametry określające pracę magazynu cross-dockingowego

Parameter	Symbol	Value	Unit
Annual transhipment on entry	P_{wy}^{R}	611750	[jlp/year]
Number of working days	d_r	300	[days]
Impact factor at the entrance	φ_{we}	1,25	[-]
Exit damming coefficient	φ_{wy}	1,25	[-]
Vehicle filling at the entrance	Z_{ST}^{we}	30	[jlp/vehicle]
Filling the vehicle at the exit	Z_{ST}^{wy}	27	[jlp/vehicle]
Working time utilization factor	φ_t	0,90	[-]
Technical availability coefficient	φ_{gt}	0,95	[-]
Work area change factor	φ_{zo}	0,95	[-]
Non-mechanical equipment maintenance cost index	γ_W	0,10	[-]
Fixed elements maintenance cost index	γ_B	0,08	[-]
The index of costs of repairs and inspections of devices	γ_T	0,12	[-]
Index of costs of repairs and inspections of control devices	γ_S	0,30	[-]
Plant cost index	γ_{kz}	0,70	[-]
Equipment depreciation cost index	α_1	0,12	[-]
Capital interest rate	α_{2T}	0,02	[-]

Source: The own study

Źródło: Opracowanie własne

VARIANT DESIGN OF THE WAREHOUSE AND WAREHOUSE PROCESS

Choosing a unit storage method and product dispensing techniques is a very complex process. When designing the warehouse, attention was paid to factors such as [16, 25]: product storage period, quantity and type of goods, type of goods packaging, rules relating to goods storage, occupational health and safety, and technological layout in the facility.

The attention was paid to the conditions that enable the optimization of the use of warehouse space and efficient work. Correctly selected technology results in solving problems that result from improper management of the warehouse space. Based on the data presented in Chapter 3, three variants of the cross-docking warehouse have been designed. They differed from each other in the technology used. Each facility has the most popular shape of cross-docking facilities, referred to as "I".

Movement of loads is carried out by the multi-touch method, which consists in unloading at the entrance to the buffer areas and then the loads are transported to the exit to the buffer areas from where the loading of external transport vehicles takes place. Pages in the warehouse permanently assigned to deliveries and shipments.

In each variant, the loading docks at the entrance and exit in the warehouse are equipped with the DOBO system (docking before opening). These are the Hörman brand docks. Taking into account the usual docks, the driver of the vehicle must first leave the car, open the rear door one by one, and only then can he start maneuvering the car. The DOBO system works completely different. The truck drives up to the ramp with the door closed. Then, after docking, the dock gate seals are inflated. Only then are the car doors opened. They can also only be opened when transhipment has started. In this way, the goods remain safe in the trailer [34].

This method protects the reloaded goods against the influence of weather conditions. The cold chain is closed. There is greater safety and time savings associated with not having to leave the car for the driver. Reloading takes place in compliance with all hygiene requirements. This means that thanks to this solution it is impossible to get into the warehouse of pollutants or animals. There is also a saving in energy costs. As already mentioned, this limits the temperature exchange. Running the gate behind or in front of the loading dock helps to prevent the formation of thermal bridges. A diagram of the DOBO system operation is presented in the fig. 1 below. The width of the loading docks used is 3.5 [m].

Variant I – frame pallet racks

The first option proposed is interim storage of dairy products in inlet and outlet buffers using pallet frame racks. They are very universal, due to their versatility, i.e. access to all goods. Therefore, the FIFO principle (first in, first out) is maintained in the warehouse. They are characterized by relatively low purchase and operating costs. It is assumed that interim storage takes place on two levels. This is related to the most possible reduction of the volume that must be cooled in the facility due to the type of goods handled. Forklifts with front support for forks and a platform for the operator were used. The designed cross-docking facility for variant I is shown in Fig. 2.

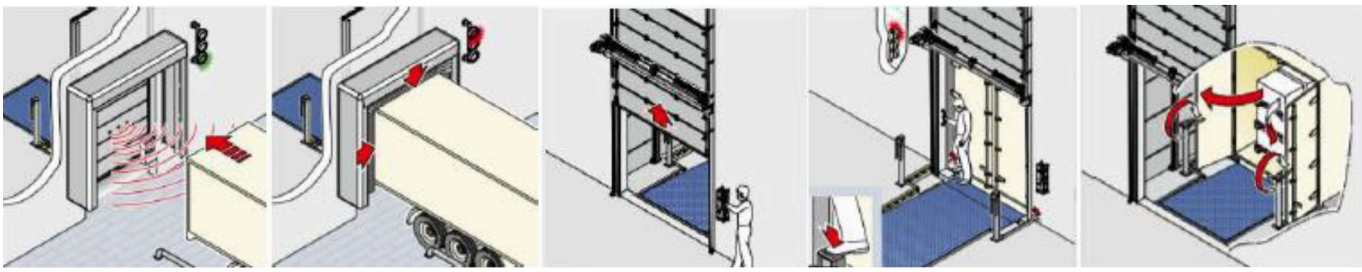

Fig. 1. Operation of loading docks with the DOBO system.
Rys. 1. Obsługa doków przeładunkowych z systemem DOBO.

Source: Own study based on [34]
Źródło: Opracowanie własne na podstawie [34]

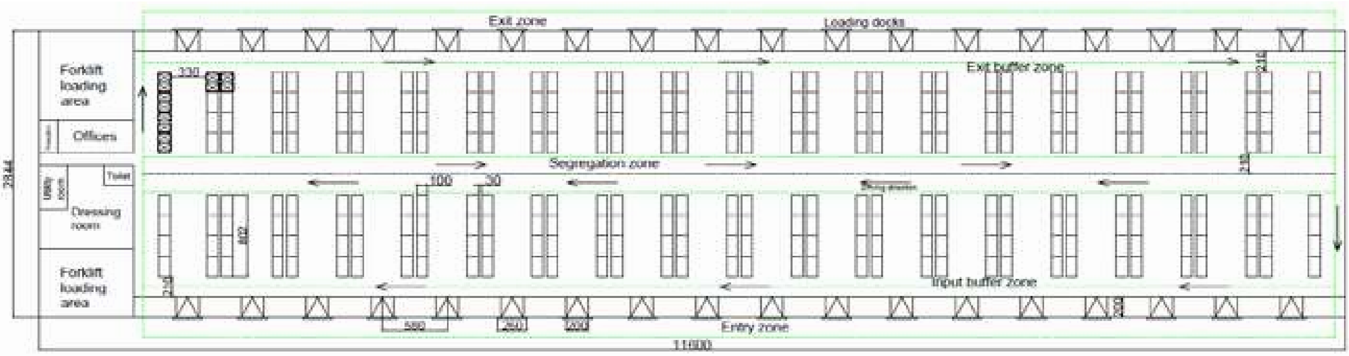

Fig. 2. Top view of the cross-docking terminal project for variant I.
Rys. 2. Widok z góry projektu terminala przeładunkowego dla wariantu I.

Source: Own study based on Auto CAD
Źródło: Opracowanie własne na podstawie Auto CAD

Variant II – flow and push-back racks

Another proposed variant uses buffering in flow and push-back racks. Flow racks were used for input buffers, while push-back racks were used for output buffers. Two types of racks are located opposite the loading dock. Interim storage in option II also takes place in two levels. The variant uses a forklift with front fork support with a platform for the operator and a telescopic mast, and a counterbalance stacker with a base mast.

Pallets are placed in the flow racks. They are built at a slight slant and contain belts with rollers. If necessary, it is possible to move the goods to the other side of the rack. Thanks to these racks, you save time when reloading products. The FIFO method is ideal for storage. The warehouse space is optimally used. The disadvantage of using flow racks is the high cost at the design stage.

In push-back racks, loading takes place by pushing a pallet with a trolley into the pallet socket. When using these racks, the storage and handling of pallets is used in the LIFO system (last in, first out).

The cross-docking warehouse with the technology described above is presented in Fig. 3.

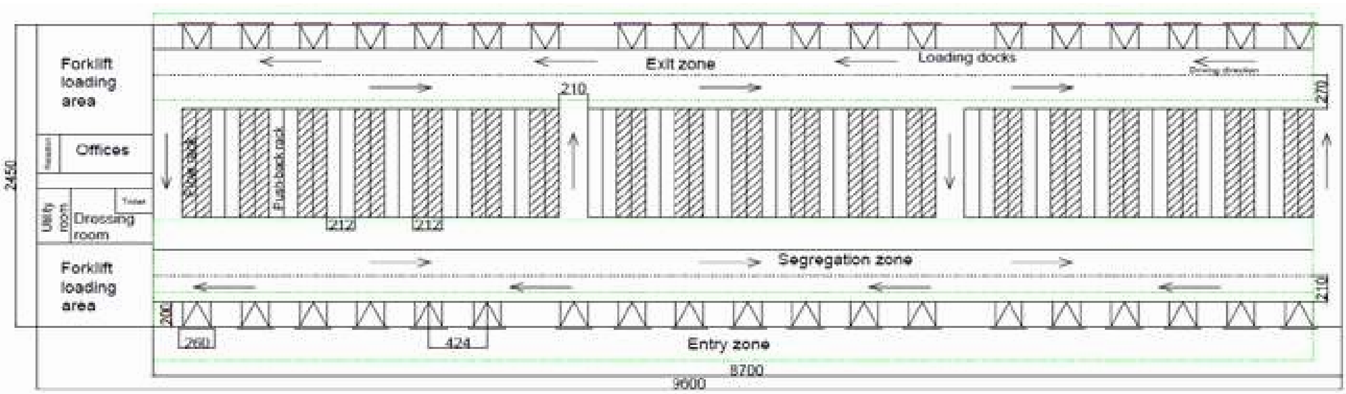

Fig. 3. Top view of the cross-docking terminal project for variant II.
Rys. 3. Widok z góry projektu terminala przeładunkowego dla wariantu II.

Source: Own study based on Auto CAD
Źródło: Opracowanie własne na podstawie Auto CAD

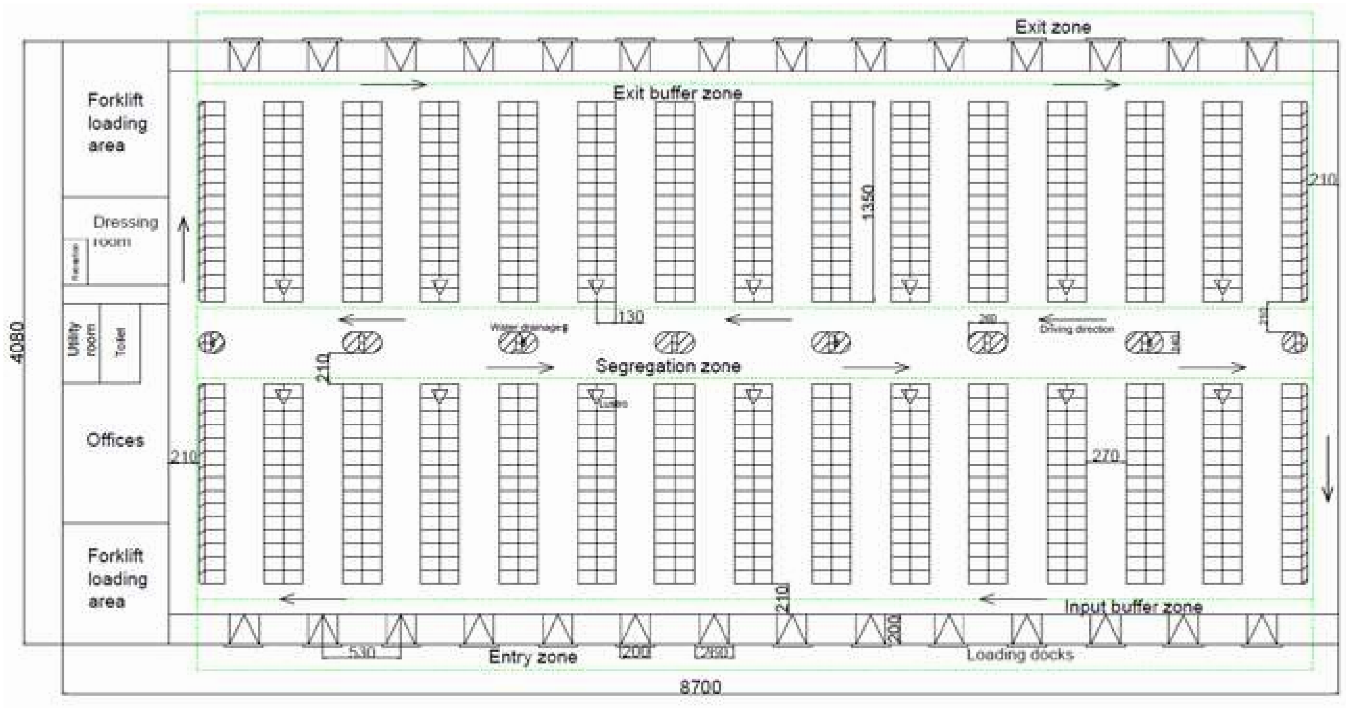

Fig. 4. Top view of the cross-docking terminal project for variant III.
Rys. 4. Widok z góry projektu terminala przeładunkowego dla wariantu III.

Source: Own study based on Auto CAD

Źródło: Opracowanie własne na podstawie Auto CAD

Variant III – buffering on the floor

The last option proposed is buffering the units on the floor. The devices used for this option are lifting trucks with an operator platform. The units are placed side by side on the floor, without the use of racks and without damming up. This is a temporary storage buffer that is used to temporarily store products that are to be sorted and released without being saved.

MULTI-CRITERIA EVALUATION OF VARIANTS WITH THE SCORING METHOD

For the evaluation of individual variants, the evaluation criteria were calculated and compiled. The first table shows the total costs and inputs for each of the options presented.

Table 3. Costs and outlays of individual variants of the cross-docking facility
Tabela 3. Koszty i nakłady dla poszczególnych wariantów obiektu cross-dockingowego

	Operating costs [zl/rok]	Investment outlays [zl]
Variant I	6 424 613,7	8 993 681
Variant II	7 019 144,1	10 370 150
Variant III	6 305 518,5	9 465 308

Source: The own study

Źródło: Opracowanie własne

The following table summarizes the number of employees and devices needed for each design variant.

Table 4. The required number of employees and devices for each variant
Tabela 4. Wymagana liczba pracowników i urządzeń dla każdego wariantu

	Employees [-]	Equipment [-]
Variant I	43	43
Variant II	41	41
Variant III	36	31

Source: The own study

Źródło: Opracowanie własne

The indicators and measures for each of the proposed design solutions of the cross-docking warehouse were also calculated. The results are shown in the table below.

Table 5. Selected measures for the assessment of design variants
Tabela 5. Wybrane mierniki i wskaźniki do oceny wariantów projektowych

	Surface meter [m^2/jłp]	Cubature meter [m^3/jłp]	Outlays for one pallet place [zl/jlp]	Cost for the unit to pass through the warehouse [zl/jlp]
Variant I	2,12	8,42	7666	10,47
Variant II	2,07	9,26	9002	11,44
Variant III	4,08	16,37	8936	10,27

Source: The own study

Źródło: Opracowanie własne

On the basis [8] of [15] and the assessment of design variants was started. By analyzing the above tables, the variants were assessed. For this purpose, one of the ranking methods was used - the scoring method. It consists in adding up the values of the standardized features for individual design variants based on the adopted criteria. The variants are ranked sequentially according to the decreasing value of the evaluation index. Thanks to this, it is possible to find the best solution objectively and to group the solutions into categories depending on the assessment.

Chapter 4 defines variants of a technical object. Then a set of goals and criteria was established. The individual goals were assigned the following weights:

- technical purpose $c = 1{:}w_1 = 0{,}3$;
- economic purpose $c = 2{:}w_2 = 0{,}6$;
- environmental purpose $c = 3{:}w_3 = 0{,}1$.

Then, the weights for the given criteria were determined on the basis of comparability, so that the weights of individual criteria were in the range [0; 1]. The sum of the weights for one target must be 1. It is presented in the table below.

Table 6. Assigning weights to individual goals and criteria

Tabela 6. Przypisywanie wag poszczególnym celom i kryteriom

Purpose	Purpose number	Purpose weight	Criterion	Criterion weight
Technical purpose	$c = 1$	0,3	Employees	0,5
			Equipment	0,5
			Sum	1
Economic purpose	$c = 2$	0,6	Operating costs	0,2
			Investment outlays	0,2
			Surface meter	0,1
			Cubature meter	0,1
			Outlays for one pallet place	0,2
			Cost for the unit to pass through the warehouse	0,2
			Sum	1
Environmental purpose	$c = 3$	0,1	Safety	0,5
			Accessibility of convenient access roads	0,5
Sum		**1**	**Sum**	**1**

Source: The own study
Źródło: Opracowanie własne

Due to the normalization of the ratings, the next step was to assign to each of the criteria whether it was a stimulant or a destimulant. Then, the values of evaluations of given decision variants were normalized. Before starting the selection of the variant, it was also necessary to determine the aggregated values of the evaluation indicators. As a result, it was possible to obtain a ranking of variants with the number of points. The steps described have been calculated and tabulated.

SUMMARY AND CONCLUSIONS

The aim of the article was to shape design variants for a cross-docking facility that served products from the dairy industry. It carries out activities such as unloading, loading, consolidation, which are carried out in the warehouse directly between external means of transport located in the reception and release docks, with the elimination of storage. This solution is used in the distribution network system. Cross docking is the optimization of storage and transport costs by shortening the supply chain.

Shortening the supply chain thanks to cross-docking facilities is a matter of ensuring the smooth functioning of logistics processes in them. This is due to the optimal organization of storage space and the use of appropriate storage systems. Since loads have to be transported as quickly as possible, the first step is to simplify your warehouse operations. Therefore, attention has been focused on shortening the routes that operators have to cover to an absolute minimum, or installing conveyor loops that will be responsible for the movement of loads in the technical facility.

In the case of high-turnover products, it is important to have direct access to them in a cross-docking facility. It is also important to optimally plan the loading docks in the warehouse. Their arrangement and communication with other areas of the facility should facilitate the effective collection and shipment of a large number of loads.

In variant I, interim storage was used in palet frame racks, which are located in the input and output buffering zone. The loads are stored in two levels. This resulted in the limitation of the cubature that needs to be cooled. The expenditure on this option turned out to be the lowest, and the maintenance costs were not much higher than in the case of variant III.

Variant II included the use of flow racks and push-back racks. Storage also takes place on two levels. However, the disadvantage of the variant is that the racks require a slope and the technical object, despite the more modern use of technology, turned out to be higher than in the case of variant I. The outlays and costs also proved to be the highest of all variants.

Variant III is a comparison of the two previous variants with the variant without the use of any shelves. Buffering takes place on the floor. This variant had the worst use of space and cubature. However, it had the lowest cost and relatively low outlay. This was due to the use of the simplest technologies.

When analyzing the conducted multi-criteria analysis using the point method, it can be noticed that variant III turned out to be the objectively best solution. It is related to the shortest time of activities performed in the terminal. This is very important for the supply chain. This also translates into a smaller number of workers and equipment needed, taking into account the other variants. Going further, it also reduces operating costs and the cost of passing one unit through a cross-docking facility. Variant III, despite the largest area, achieved low investment outlays. This was due to the lack of shelving and the low number of required devices.

Variant I was the second in the preferred order of choice. It was distinguished by the lowest expenditures. Its surface was much smaller than in variant III and the technology used was cheaper than in variant II. In variant I, the costs of cooling the

Table 7. Evaluation of individual variants
Tabela 7. Ocena poszczególnych wariantów

Purpose	Purpose weight	Criterion	Criterion weight	Normalization	Variant 1			Variant 2			Variant 3		
					Evaluation	Evaluation after normalization	Points	Evaluation	Evaluation after normalization	Points	Evaluation	Evaluation after normalization	Points
Technical	0,3	Number of employees	0,50	Destimulant	43	0,84	0,126	41	0,88	0,126	36	1,00	0,150
		Number of equipment	0,50	Destimulant	43	0,72	0,108	41	0,76	0,108	31	1,00	0,150
Economic	0,6	Operating costs	0,17	Destimulant	8993681	1,00	0,102	10370150	0,87	0,088	9465308	0,95	0,097
		Investment outlays	0,17	Destimulant	6424614	0,98	0,100	7019144	0,90	0,092	6305519	1,00	0,102
		Surface meter	0,16	Destimulant	2,12	0,98	0,094	2,07	1,00	0,096	4,08	0,51	0,049
		Cubature meter	0,16	Destimulant	8,42	1,00	0,096	9,26	0,91	0,087	16,37	0,51	0,049
		Outlays for one pallet place	0,17	Destimulant	7666	1,00	0,102	9002	0,85	0,087	8936	0,86	0,088
		Cost for the unit to pass through the warehouse	0,17	Destimulant	10,47	0,98	0,100	11,44	0,90	0,092	10,27	1,00	0,102
Environmental	0,1	Safety	0,50	Stimulator	1,00	0,92	0,045	1,91	1,51	0,087	1,1	1,00	0,050
		Accessibility of convenient access roads	0,50	Stimulator	3	1,00	0,050	3	1,00	0,050	3	1,00	0,003
SUM	**1**				**SUM**		**0,923**	**SUM**		**0,924**	**SUM**		**0,839**

Source: The own study
Źródło: Opracowanie własne

technical facility are lower than in variant III. On the other hand, the advantage of variant II is the low area and cubature index. This variant was the worst. This is due to the long cycle times which are caused by the high average stacking heights or picking up pallet load units from the racks. This option is the most time consuming from a supply chain point of view. As already mentioned, this variant required the greatest expenditure to use the racks used in it. It also used expensive counterbalanced trolleys as it was important to provide some tractive effort to service the push-back racks. Safety in the warehouse was also noted. It is related to the performance of specific activities.

PODSUMOWANIE I WNIOSKI

Celem artykułu było ukształtowanie wariantów projektowych dla obiektu cross-dockingowego, który obsługiwał produkty z branży mleczarskiej. Realizuje on czynności takie jak rozładunek, załadunek, konsolidacja, które są wykonywane w magazynie bezpośrednio pomiędzy zewnętrznymi środkami transportu zlokalizowanymi w dokach na wejściu i wyjściu, z wyeliminowaniem składowania. Rozwiązanie to stosowane jest w systemie sieci dystrybucji. Cross docking to optymalizacja kosztów magazynowania i transportu poprzez skrócenie łańcucha dostaw.

Skrócenie łańcucha dostaw dzięki obiektom cross-dockingowym to kwestia zapewnienia w nich sprawnego funkcjonowania procesów logistycznych. Wynika to z optymalnej organizacji przestrzeni magazynowej oraz zastosowania odpowiednich systemów składowania. Ponieważ produkty z branży mleczarskiej muszą być transportowane w jak najkrótszym czasie, pierwszym krokiem jest uproszczenie operacji magazynowych. Dlatego też zwrócono uwagę na skrócenie do absolutnego minimum tras, które muszą pokonywać operatorzy, czy też zaimplementowanie odpowiedniej technologii, która jest odpowiedzialna za przemieszczanie i obsługę ładunków w obiekcie technicznym. W przypadku produktów o wysokiej rotacji ważny jest bezpośredni dostęp do nich w obiekcie cross-dockingowym. Istotne jest również optymalne zaplanowanie doków przeładunkowych w magazynie. Ich rozmieszczenie i komunikacja z innymi obszarami obiektu powinny ułatwiać sprawne pobieranie i wysyłanie dużej liczby ładunków.

W wariancie I zastosowano składowanie tymczasowe w regałach ramowych paletowych, które znajdują się w strefie buforowania wejścia i wyjścia. Ładunki składowane są na dwóch poziomach. Spowodowało to ograniczenie kubatury wymagającej chłodzenia. Nakłady na ten wariant okazały się najniższe, a koszty utrzymania były niewiele wyższe niż w przypadku wariantu III.

W wariancie II zastosowano regały przepływowe i regały typu push-back. Składowanie również odbywa się na dwóch poziomach. Wadą wariantu jest jednak to, że regały wymagają nachylenia, a obiekt techniczny, mimo nowocześniejszego zastosowania technologii, okazał się wyższy niż w przypadku wariantu I. Nakłady i koszty również okazały się najwyższe ze wszystkich wariantów.

Wariant III to porównanie dwóch poprzednich wariantów z wariantem bez zastosowania jakichkolwiek regałów. Buforowanie odbywa się na posadzce. Wariant ten charakteryzował się najgorszym wykorzystaniem przestrzeni i kubatury. Miał jednak najniższy koszt i stosunkowo niskie nakłady. Wynikało to z zastosowania najprostszych technologii.

Skupiając uwagę na przeprowadzonej analizie wielokryterialnej metodą punktową można zauważyć, że obiektywnie najlepszym rozwiązaniem okazał się wariant III. Jest to związane z najkrótszym czasem wykonywania czynności w terminalu. Jest to bardzo istotne z punktu widzenia łańcucha dostaw produktów z branży mleczarskiej. Przekłada się to również na mniejszą liczbę potrzebnych pracowników i urządzeń, biorąc pod uwagę pozostałe warianty. Idąc dalej, zmniejsza to również koszty operacyjne oraz koszt przejścia jednej jednostki przez obiekt cross-dockingowy. Wariant III, mimo największej powierzchni, osiągnął niskie nakłady inwestycyjne. Wynikało to z braku regałów i małej liczby wymaganych urządzeń.

Wariant I stał drugi w preferowanej kolejności. Wyróżniał się najniższymi nakładami. Jego powierzchnia była znacznie mniejsza niż w wariancie III, a zastosowana technologia tańsza niż w wariancie II. W wariancie I koszty chłodzenia obiektu technicznego są niższe niż w wariancie III. Natomiast zaletą wariantu II jest niski wskaźnik powierzchni i kubatury. Ten wariant okazał się najgorszy.

Wynika to z długich czasów cykli, które wynikają z czynności układania oraz pobierania jednostek ładunkowych paletowych z regałów. Wariant ten jest najbardziej czasochłonny z punktu widzenia łańcucha dostaw produktów mlecznych. Jak już wspomniano, wariant ten wymagał największych nakładów na wykorzystanie zastosowanych w nim regałów. Wykorzystano w nim również drogie wózki z przeciwwagą, gdyż ważne było zapewnienie siły pociągowej do obsługi regałów push-back. W analizie zwrócono uwagę również na bezpieczeństwo w magazynie.

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