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Determinants of site selection for the warehouses of food logistic providers

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Abstract
Most food products are perishable and very time-sensitive. In addition, food products are essential goods that are always in market demand. Therefore, the proximity of the warehouse location to the market is crucial for the daily delivery of food products. The current study aimed to identify the effective criteria for the selection of food warehouse location and then rank those criteria. To achieve this goal and develop a conceptual framework, a semi-structured questionnaire was employed, utilizing a group of experts and specialists in decision-making. Findings of this study revealed that all group members from various specialties highlighted the importance of the land suitability criterion and its subcriteria, ranking it as their top priority. In the analysis of land suitability, the economic factor including land price and market proximity had the highest frequency of responses. Furthermore, the spatiotemporal criterion and the logistics network had a high response frequency, which were ranked second and third, respectively. The implications of the results of this study on the selection of food warehouse locations are based on the efficiency and effectiveness of logistic operations. By comprehensively addressing these criteria, the chances of obtaining an effective and resilient network for food product storage will increase, taking into account operational efficiency and economic viability. In this context, logistics policymakers will be able to plan the storage location of food products under the principles of efficiency, sustainability, and resilience in facing various challenges.

Keywords Land suitability · Land price · Market proximity · Transportation infrastructure

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1 Introduction

Food products are stored in warehouses known as basic infrastructure before their distribution and sale (Han et al., 2021; Riesenegger & Hübner, 2022). Food warehouses provide storage facilities for products to allow for handling, i.e., receiving, transferring, picking, and shipping. In this way, flow of food products in the supply chain is improved (Mohan et al., 2023; Onwude et al., 2020). The physical proximity of warehouses to food production centers is common and this helps them to control their operations. Food production centers often require extra storage capacity due to factors such as heightened demand or peak harvest seasons. However, constructing additional warehouse facilities poses challenges due to the substantial initial investment costs (Custodio & Machado, 2020; Rebelo et al., 2021). Furthermore, physical distance between warehouses and food production centers contributes to elevated transportation expenses for product delivery to the warehouses (Kang, 2020; Cecilia et al., 2024). These warehouse-related costs typically constitute nearly one-third of the overall logistics expenditure. Hence, selecting an optimal warehouse location is imperative for efficient supply chain management and holds strategic significance (Abdul Rahman et al., 2023; Zaman et al., 2023).

The right location to store food products can increase the profitability of the production centers and reduce the risk and uncertainty for the supply chain (Daneshvar et al., 2023; Gholami-Zanjani et al., 2021; de Castro Moura Duarte & Picanço Rodrigues, 2024). Furthermore, managers will be able to quickly react to increased demand. As a result, consumer satisfaction is improved and the competitive advantage of the production center is enhanced (Pei et al., 2020; Reklitis et al., 2021). Therefore, warehouse location is important from the three dimensions of capital investment, operating cost, and consumer service and is almost an irreversible decision (Ocampo et al., 2020; Saha et al., 2023). The placement of a warehouse within a supply chain network significantly influences the efficiency and speed of the entire supply chain (Nagarajan et al., 2022; Vafaei et al., 2020). Celik Turkoglu and Erol Genevois (2020) argued that the selection of a warehouse location not only entails site selection considerations but also requires a comparison of the local market characteristics with the overall objectives of the production center. In this regard, the first warehouse location theory focuses on minimizing the total distance between the warehouse and a set of local customers (Lee et al., 2020), which has received much attention in the current literature so far.

Various techniques have been employed to address the warehouse location problem, ranging from mathematical programming approaches (e.g., Gao, 2021; Kübler et al., 2020; Rath & Gutjahr, 2014; Wang et al., 2021) to searching algorithms (such as Kordos et al., 2020; Misni et al., 2020; Wang & Xia, 2020). Considering several criteria in choosing a warehouse location is a direct consequence of this issue due to the existence of different influential factors in the decision-making process. However, the warehouse location selection process using mathematical programs is limited to only considering the criteria that can be expressed as a mathematical expression, but multi-criteria decision-making methods have become a popular technique in dealing with this limitation (Ocampo et al., 2020; Öznil et al., 2020; Ulutaş et al., 2021).

Studies on warehouse location selection among different sites have usually focused on defining the criteria that are commonly used in the actual decision-making process (Ehsanifar et al., 2021; Kang, 2020; Saha et al., 2023). However, warehouse location selection has

semi-structured issues, which are complex and multi-criteria (Li et al., 2020; Radwan et al., 2021). Although land suitability analysis and warehouse location selection are complex issues, the semi-structured questionnaire can address the concerns of effective decision-making in this regard (Gergin et al., 2023; Sanjari-Parizi et al., 2024). Moreover, the semi-structured questionnaire helps to identify the appropriate criteria and choose the best warehouse location after evaluating the information recorded by experts and specialists (Ocampo et al., 2020; Sharma et al., 2023; Yildiz & Ozkan, 2024). In this context, the semi-structured questionnaire was used in the survey to obtain information as a result of aligning the most reliable consensus process of the group of experts and specialists. Therefore, using semi-structured questionnaire was recognized as the best decision option for the location of the food products warehouse.

Various researchers (such as Gergin & Peker, 2019; Li et al., 2020; Ocampo et al., 2020; Yazdani et al., 2020) have studied the factors influencing the choice of warehouse location. Gergin and Peker (2019) reviewed the previous research on warehouse location selection and provided information on success factors and methods. Their results showed that the most common success factors were based on cost criteria and the most used methods were multi-criteria decision-making methods. Li et al. (2020) ranked and selected the warehouse location using a visual analytical approach. Accordingly, an interactive framework for the generation and discovery of alternative warehouses was proposed. Based on this case study, they were able to evaluate the efficiency of the systems and they contributed to experts in solving the issue of discovering the ideal warehouse for retail logistics management. Ocampo et al. (2020) addressed a warehouse location decision issue in a product distribution firm, considering multiple decision criteria within a group decision-making context. Their findings highlighted the prioritization of criteria that minimized product distribution costs within the study area. Furthermore, the decisions made by respondents and their prioritization of criteria did not influence each other, indicating the distinct knowledge and expertise of the participants. In addition, Yazdani et al. (2020) developed a two-stage decision-making model, i.e., first comparing communities to identify efficient options and second, evaluating the performance of efficient communities to discover the best location to establish logistics centers in Spain. In this context, uncertainty and ambiguity in decision-makers' judgments were considered in the evaluation process. In addition, sensitivity analysis was performed to confirm the robustness of the obtained results. The novelty of this study is that the criteria influencing the warehouse location selection were determined by the semi-structured questionnaire. The experts and specialists within the respondent group, encompassing diverse fields such as land management, environmental science, economics, and geography, play integral roles in evaluating various criteria. Furthermore, this study transcends regional boundaries with potential implications on a global scale. Consequently, its objective is to identify and prioritize the criteria influencing the selection of storage locations for food products, leveraging the insights of experts and specialists.

2 Conceptual framework

Most of the agricultural products are perishable and very sensitive to time (Daneshvar et al., 2023). Moreover, agricultural products are among the essential goods and there is always a market demand for them (Javaid et al., 2023). Accordingly, the storage location of agricul-

tural products, i.e., proximity to the market, is important for the daily delivery of these products to the market (van der Lee et al., 2020). Researchers (e.g., Biuki et al., 2020; Mishra et al., 2024; Okpala & Korzeniowska, 2023) believed that the selection of storage location and type can affect the supply chain in different ways and have important implications for the efficiency and effectiveness of logistics operations. In this context, the right storage location ensures that the products are strategically placed along the supply chain, thereby reducing transportation time and minimizing transportation costs (Biuki et al., 2020; Mishra et al., 2024). Furthermore, proper storage of agricultural products preserves their quality, integrity, and safety, hence the products reach consumers in optimal conditions (Okpala & Korzeniowska, 2023). However, externalities should be taken into account. For example, the time and transportation costs of other commuters will increase due to an additional logistics center, which should be minimized at the same time.

Land suitability significantly influences the site selection for warehousing, considering different physical, environmental, economic, and social dimensions. The physical dimension assesses land suitability in terms of soil quality, i.e., soil suitability for different types of storage, topography, i.e., land features to identify suitable locations for storage facilities, and drainage, i.e., water drainage patterns to prevent flooding (Özkan et al., 2020). The environmental dimension evaluates land suitability in terms of proximity to water bodies, i.e., the impact of water bodies on storage facility location, and protected areas, i.e., hot spots of biodiversity that limit the development of storage facilities (Huggins et al., 2022). The economic dimension assesses land suitability in terms of land price, i.e., land costs and availability for the investment of storage facilities, and market proximity, i.e., proximity to markets and transportation centers (Nong, 2022). The regulatory dimension evaluates land suitability in terms of zoning regulations, i.e., understanding local zoning laws and regulations governing land use for storage facilities, and environmental regulations, i.e., compliance with environmental regulations related to waste management, emissions, and pollution control (Ustaoglu & Aydınoglu, 2020). Different regions may have different environmental regulations and requirements related to land use and development. Selecting suitable land contributes to avoiding legal and environmental issues and ensures compliance with relevant regulations.

When determining the warehouse location for the storage of agricultural products in the network, the role of the storage facility in the logistics network and the design of the transport flow should be considered (Pavlenko et al., 2020). Access to transportation infrastructure, including roads, railways, and ports is another factor in determining the warehouse location (Champagne & Dubé, 2023). In addition, alignment with supply chain dynamics, e.g., different demand patterns and distribution networks, should be considered (Soori et al., 2023). Warehouse location is also determined based on market demand for agricultural products and required storage capacity (Daneshvar et al., 2023).

The selection of the optimal location for agricultural product storage involves careful consideration of spatiotemporal factors. Spatially, proximity to production areas, transportation networks, and markets is critical for minimizing logistical costs and ensuring timely distribution (Aljohani, 2023). The climate and environmental conditions of the chosen location are paramount, aligning with the specific storage requirements of diverse agricultural products (Pajić et al., 2024). Temporally, the ability to manage seasonal fluctuations in the supply of agricultural products is crucial, which ensures the availability of sufficient inventory during peak demand periods and avoids wastage of storage space in off-seasons (Huang

et al., 2023). In addition, understanding the temporal aspects of transportation flows, including peak seasons and potential delays, is essential for efficient supply chain management (Zaalouk et al., 2023).

By comprehensively addressing these criteria, an effective and resilient network for agricultural product storage is guaranteed, taking into account operational efficiency and economic viability. In this context, logistics policymakers will be able to plan the storage location of agricultural products under the principles of efficiency, sustainability, and resilience in facing various challenges. Figure 1 shows a conceptual view of the factors influencing the warehouse location.

3 Methodology

The semi-structured questionnaire implements the feedback mechanism of experts and specialists in several stages of questions while maintaining the anonymity of the responses (Schmalz et al., 2021). The purpose of the semi-structured questionnaire is to develop consensus forecasts of the future with the help of experts and specialists' opinions. Furthermore, this way can be applied to search for information that builds consensus as part of a group of respondents and educates the group of respondents on different aspects and

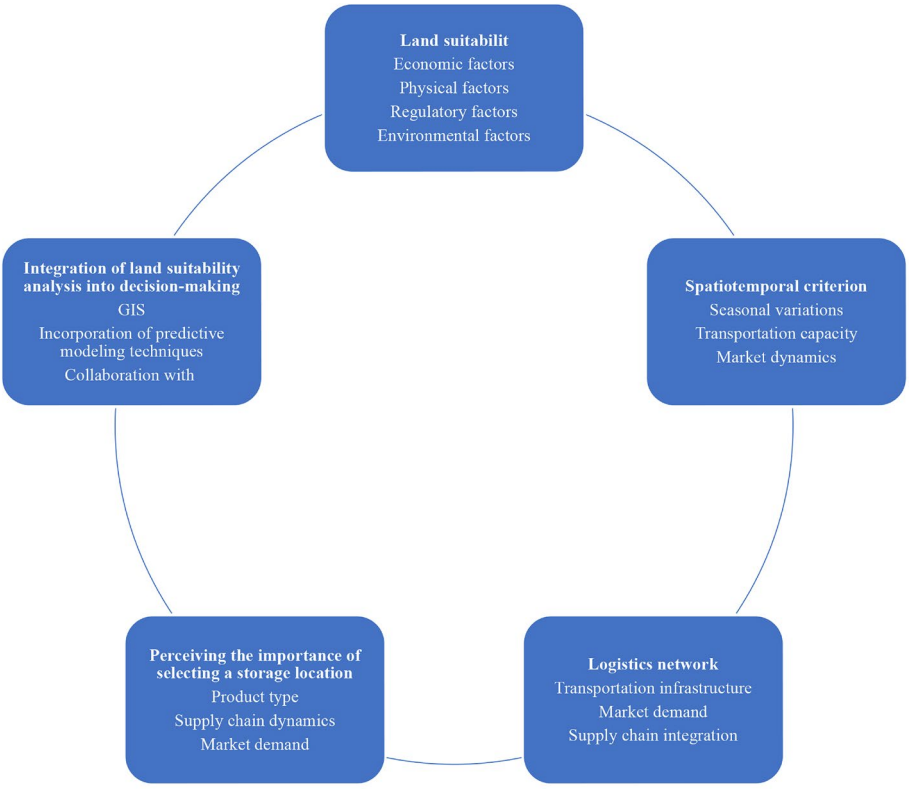

Fig. 1 Factors influencing the warehouse location determination

related issues. Accordingly, the interview can be continuously repeated until a consensus is achieved (Sforzini et al., 2022). However, three iterations are often enough to gather the required information and achieve a consensus. In this context, the questions and how to use the information should be clearly and correctly explained to the group members of 24 experts and specialists through online interview.

3.1 Delphi

The Delphi method systematically implements the feedback mechanism of experts and specialists in several stages of questions while maintaining the anonymity of the responses (Schmalz et al., 2021). This method is a structured communication technique using a questionnaire that relies on multiple experts and specialists developed as an interactive forecasting method (Fig. 2). The Delphi technique is a modification of brainstorming and survey methods (Ismail & Taliep, 2023).

3.2 Criteria and weighting

Criteria and measurements were considered to evaluate the warehouse location for factors and real conditions. The response frequency of the group members to each criterion was used for weighting. The criteria for decision-making regarding the appropriate location of the food product warehouse are as follows: perceiving the importance of selecting a storage location, land suitability, logistics network, spatiotemporal criterion, and integration of land suitability analysis into decision-making.

The group members were from different disciplines related to the issue of choosing the location of food warehouses, consisting of land specialists, environmental specialists, economists, and geographers. Each of the experts and specialists is obliged to provide an objective assessment and to make the location suitable for deciding the storage of food products. Evaluations made by experts and specialists in different fields are shown in various colors from a technical standpoint.

4 Results

The characteristics of the respondents are shown in Table 1. According to Table 1, 11 respondents (46%) are female and 13 ones (54%) are male. Respondents had various specialized fields. In this regard, 10 respondents (41%) are from the environmental field and 10 respondents (25%) are economists. In addition, four respondents (17%) are land specialists and four respondents (17%) are geographers.

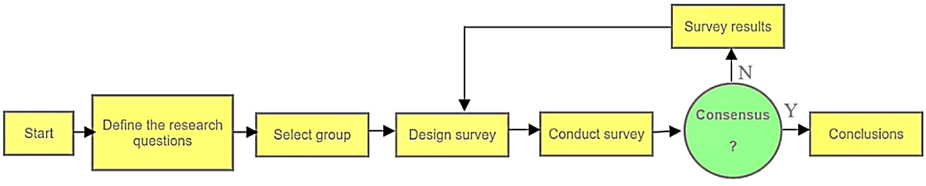

Fig. 2 Communication structure Delphi technique

Table 1 The characteristics of the respondents

Characteristic	Sub-characteristic	The number of respondents	Frequency (%)
Gender	Female	11	46
	Male	13	54
Group disciplines	Land specialists	4	17
	Environmental specialists	10	41
	Economists	6	25
	Geographers	4	17

Table 2 The results of the effective criteria on the warehouse location selection based on the group opinion

No	Criteria	Group disciplines				SUM
		Land specialists	Environmental specialists	Economists	Geographers	
1	Perceiving the importance of selecting a storage location	2	6	4	3	15
2	Land suitability	4	14	17	4	39
3	Logistics network	2	4	8	2	16
4	Spatiotemporal criterion	1	5	8	3	17
5	Integration of land suitability analysis into decision-making	1	3	3		7

Note: The values indicate the frequency of responses to each criterion under study

Six decision criteria for choosing the best warehouse location for food products have been identified through a semi-structured questionnaire (Appendix A). Table 2 shows the results of the group members' survey on the effective criteria for warehouse location determination by different disciplines. Based on the findings presented in Table 2, land specialists accorded the highest importance to land suitability analysis, followed by the significance attributed to selecting a storage location, the logistics network, spatiotemporal criteria, and integrating land suitability analysis into decision-making processes. Environmental specialists similarly assigned the highest importance to land suitability analysis, followed by considerations such as the importance of selecting a storage location, spatiotemporal criteria, the logistics network, and the integration of land suitability analysis into decision-making processes (Table 2). However, as depicted in Table 2, economists primarily prioritized land suitability, followed by an equal weighting of the logistics network and spatiotemporal criteria. Finally, considerations regarding the importance of selecting a storage location and integrating land suitability analysis into decision-making processes were noted. Geographers have given importance to land suitability, the spatiotemporal criterion, perceiving the importance of selecting a storage location, and the logistics network respectively (Table 2). Finally, the highest frequency of responses based on the entire members is land suitability analysis, spatiotemporal criteria, and logistics network.

Table 3 shows the assessment results of experts and specialists in detail for different subcriteria. The results of Table 3 show that for the first criterion, i.e., perceiving the importance of selecting a storage location, three sub-criteria of product type, supply chain dynamics, and market demand are important, respectively.

Table 3 The final results of the assessment of experts and specialists

Criteria	Sub-criteria	Value assessment
Perceiving the importance of selecting a storage location		15
	Product type	9
	Market demand	2
	Supply chain dynamics	4
Land suitability		39
	Physical factors: soil quality, topography, drainage.	9
	Environmental factors: proximity to water bodies, and protected areas.	5
	Economic factors: land price, market proximity.	19
	Regulatory factors: zoning regulations, environmental regulations.	6
Logistics network		16
	Transportation infrastructure	13
	Supply chain integration	1
	Market demand	2
Spatiotemporal criterion		17
	Seasonal variations	6
	Transportation capacity	6
	Market dynamics	5
Integration of land suitability analysis into decision-making		7
	Utilization of Geographic Information Systems (GIS)	3
	Incorporation of predictive modeling techniques	2
	Collaboration with stakeholders	2

Note: The values indicate the frequency of responses to each criterion under study

Land suitability analysis has four sub-criteria, i.e., physical factor, environmental factor, economic factor, and regulatory factor, of which the economic factor (including land price, and market proximity) has gained the highest importance (Table 3). After that, experts and specialists have given importance to the physical factors, i.e., soil quality, topography, and drainage (Table 3). The results of Table 3 show that regulatory (zoning regulations, environmental regulations) and environmental (proximity to water bodies, and protected areas) factors compared to economic and physical factors were less important in land suitability analysis.

The number of responses to the transportation infrastructure in the logistics network has the highest frequency while the market demand and the integration of the supply chain integration have received less attention from group members (Table 3).

In addition, the results of Table 3 show that the experts and specialists paid equal attention to the spatiotemporal sub-criteria, namely, seasonal variations, transportation capacity, and market dynamics, and they have almost the same importance.

In the criterion of integration of land suitability analysis into decision-making, there are three sub-criteria, i.e., utilization of Geographic Information Systems (GIS) for spatial analysis and visualization of land suitability factors, incorporation of predictive modeling techniques to forecast future land suitability and storage facility requirements, and collabo-

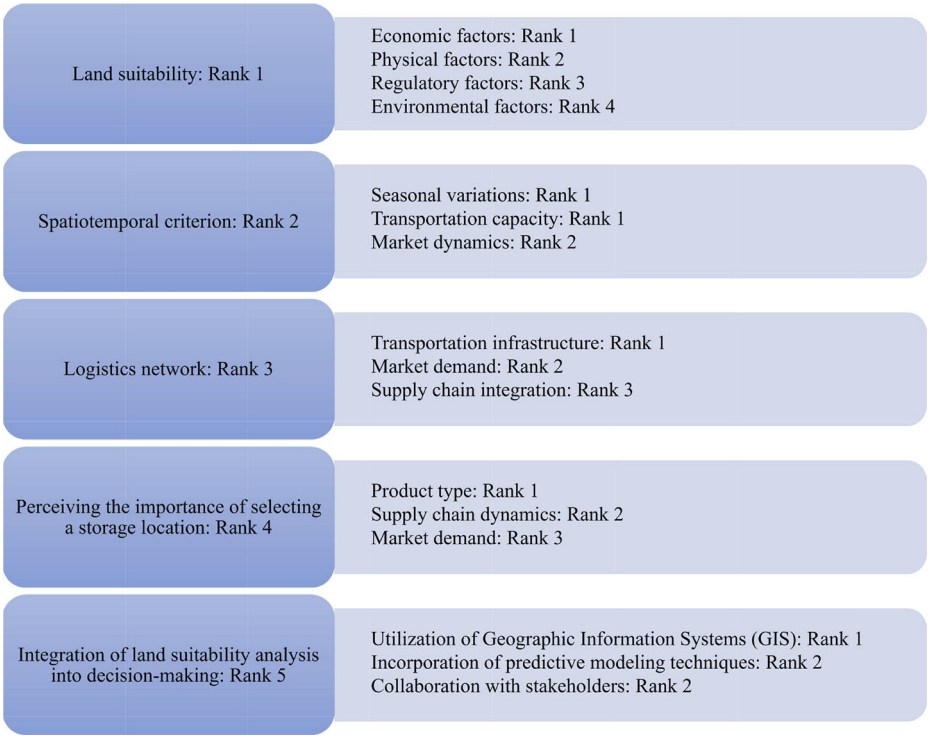

Fig. 3 Ranking the criteria for warehouse location selection

ration with stakeholders, including logistic providers, policymakers, and local communities to ensure informed decision-making and sustainable development (Table 3). The frequency of responses on these three criteria is almost the same.

Figure 3 shows the ranking of five criteria affecting the warehouse location selection based on the group members' opinions. According to the results of Fig. 3, the land suitability analysis has the first rank and the sub-criterion of economic factors has the first rank among other sub-criteria. Almost all the group members have pointed to economic factors, namely land price and market proximity. Therefore, evaluating land costs and availability to determine the investment feasibility of storage facilities, as well as evaluating proximity to markets and transportation centers to minimize transportation costs are important factors in selecting a warehouse location and one should pay attention to them.

5 Discussion

Based on the frequency of responses from experts and specialists evaluating all criteria to determine warehouse locations, the final assessment concluded that land suitability emerged as the most important criterion, securing the top rank. Notably, experts across various specialized fields, including land, environment, economics, and geography, reached a consensus on its significance. After the land suitability, group members have given the most

importance to the spatiotemporal criterion and the logistics network. The results of this study have been emphasized in other research on the importance of land suitability, space-time, and logistics network which are addressed in the following.

Land suitability significantly influences the site selection for warehousing, considering different physical, environmental, economic, and social dimensions. The physical dimension assesses land suitability in terms of soil quality, i.e., soil suitability for different types of storage, topography, i.e., land features to identify suitable locations for storage facilities, and drainage, i.e., water drainage patterns to prevent flooding (Özkan et al., 2020). The environmental aspect assesses land suitability based on its proximity to water bodies, considering the influence of water bodies on the location of storage facilities, and protected areas, which are biodiversity hotspots restricting the development of storage facilities (Huggins et al., 2022). The economic dimension evaluates land suitability based on two main factors: land price, which includes land costs and availability for investment in storage facilities, and market proximity, which refers to the proximity of the land to markets and transportation centers (Nong, 2022).

The regulatory dimension assesses land suitability through two key aspects: zoning regulations, involving an understanding of local laws and regulations governing land use for storage facilities, and environmental regulations, which entail compliance with regulations concerning waste management, emissions, and pollution control (Ustaoglu & Aydınoglu, 2020). Different regions may have different environmental regulations and requirements related to land use and development. Selecting suitable land contributes to avoiding legal and environmental issues and ensures compliance with relevant regulations.

The selection of the optimal location for food product storage involves careful consideration of spatiotemporal factors. In terms of spatial considerations, being close to production areas, transportation networks, and markets is crucial for minimizing logistical costs and ensuring timely distribution (Aljohani, 2023). The climate and environmental conditions of the chosen location are paramount, aligning with the specific storage requirements of diverse food products (Pajić et al., 2024). Temporally, the ability to manage seasonal fluctuations in the supply of food products is crucial which ensures the availability of sufficient inventory during peak demand periods and avoids wastage of storage space in off-seasons (Huang et al., 2023). In addition, understanding the temporal aspects of transportation flows, including peak seasons and potential delays, is essential for efficient supply chain management (Zaalouk et al., 2023).

When deciding on the warehouse location to store food products within the network, it's essential to consider the storage facility's role within the logistics network and the design of transportation flow. (Pavlenko et al., 2020). Access to transportation infrastructure, including roads, railways, and ports, is another factor in determining the warehouse location (Champagne & Dubé, 2023). Furthermore, it's important to consider alignment with supply chain dynamics, such as varying demand patterns and distribution networks (Soori et al., 2023). The selection of warehouse locations also depend on market demand for food products and the necessary storage capacity (Daneshvar et al., 2023).

The semi-structured questionnaire is one of the useful tools for ranking the factors affecting the warehouse location selection which is used by managers and policymakers as all the responsible members of the group participate in adjusting goals. Experts and specialists can give their opinions in a specific related policy field. The names of experts and specialists are not taken into account to prevent the influence of one member on another, and sufficient

time is given to the members of the group to examine the questions to avoid psychological pressure.

6 Conclusion

Most food products are perishable and very time-sensitive. In addition, food products are essential goods that are always in market demand. Accordingly, the warehouse location for food products, that is, proximity to the market, is important for the daily delivery of these products to the market. Researchers believe that the selection of warehouse location and type can affect the supply chain in several ways and have important implications for the efficiency and effectiveness of logistics operations. In this context, the right warehouse location ensures that products are strategically located along the supply chain, thereby reducing transit time and minimizing transportation costs. In addition, proper storage of food products preserves their quality, integrity, and safety, hence products reach consumers in optimal conditions. The current study aims to find out the effective criteria for the selection of the food warehouse location and then rank those criteria. To this aim, the semi-structured questionnaire based on a decision-making group of experts and specialists was used. The results of this study show that all group members in different specialties emphasized the land suitability criterion and its sub-criteria and placed the criterion in the first rank. In the analysis of land suitability, the economic factor including land price and market proximity had the highest frequency of responses. Furthermore, the spatiotemporal criterion and the logistics network had a high response frequency, which ranked second and third, respectively.

The semi-structured questionnaire uses descriptive ways to obtain valid information on policy outcomes with the contribution of a survey of various experts and specialists. The theoretical evaluation of the decisions is followed by extracting and establishing the explicit criteria of the group members. In this way, the goals of policymakers and managers are a valuable source as all specialties have a contribution to the adjustment and implementation of policies. They are also involved in the adjustment of criteria.

The implications of the results of this study on the selection of food warehouse locations are based on the efficiency and effectiveness of logistic operations. In this regard, the decision-makers were able to identify the key criteria that were ultimately ranked. When the questionnaire was sent to the group members, these experts and specialists perceived the questions well, knew them, and had a good command of the topic. The final result was when experts and specialists were asked to fill in the sent questionnaire. They created different ideas and criteria to determine the warehouse location and then the group members sent the questionnaires to the researchers and the final decision-makers. The next step was to summarize all the obtained responses. When prioritization was implemented, the best criteria and sub-criteria which were effective in selecting a warehouse location for food products were identified.

By comprehensively addressing these criteria, the chances of obtaining an effective and resilient network for food product storage will increase, taking into account the operational efficiency and economic viability. In this context, logistics policymakers will be able to plan the storage location of food products under the principles of efficiency, sustainability, and resilience in facing various challenges. To guide future research, it is suggested to estimate the effect size of each of the criteria on the warehouse location selection, and by consider-

ing each of these criteria, the probability of selecting the right location for a food products warehouse can be measured quantitatively.

The limitation of this study is that the importance coefficient of the criteria and sub-criteria was not available, but the prioritization was determined based on the frequency of responses. Thus, future studies are suggested to measure the importance of the criteria and sub-criteria and make the ranking accordingly.

Appendix A

Delphi questionnaire

1. Why is choosing the correct location and type of storage important and how should logistic providers select the best location for packed agricultural storage (i.e., foods, fibers, fuels, medicinal products, etc.)?
2. How can land suitability affect of site selection by considering location and price for warehousing?
3. What criteria should be considered when determining the location of the warehouse for agricultural storage in network and transport flow design?
4. What are the main spatio-temporal factors when selecting the best location for agricultural storage?
5. Other important issues to be considered (if any).
6. Personal information

    6.1 First and last name
    6.2 Email address

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Data availability Once the manuscript is accepted the data will be archived in the repository of the University of Liège and a link will be made available.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate Not applicable.

Consent for publication Not applicable.

Conflict of interest The authors declare no conflict of interest.

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