Evaluation of the Logistics System Development Scenarios – Case Study of the Trading Company

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The paper presents the procedure for selecting a scenario for the development of the logistics system in a company with a developed trading and logistics network, but also with the significant supply problems. In order to solve the existing logistics problems, but also to respond to future requirements and business plans, four logistics system development scenarios are defined. Each scenario has certain characteristics which can be seen as the advantages or disadvantages in the comparative analysis. Since the choice of development scenarios depends on several factors, their ranking in terms of different criteria requires the application of multi-criteria decision-making (MCDM) methods. A hybrid model based on a combination of the fuzzy AHP (Analytical Hierarchy Process) and fuzzy VIKOR (Višekriterijumska Optimizacija i kompromisno Rešenje) methods was used to solve the problem.

Key words: logistics system, development scenario, multi-criteria decision-making, fuzzy AHP, fuzzy VIKOR

1. INTRODUCTION

Today, trading companies are facing increasingly fierce competition, which force them to search for the new ways to improve their business [1]. The development of new strategies and business models based on the improvement of logistics activities are becoming a key weapon in the fight for a better place in the market [2, 3]. In this process, it is necessary to adequately identify and explain the role of logistics in the company's strategy and achieving a competitive advantage [4, 5], which largely depends on whether the company carries out logistics activities itself (insourcing) or hires specialized logistics service providers (outsourcing) [6]. Although for the past few decades the outsourcing has been seen as a trend for companies whose core business is not logistics, insourcing still stands out as a business strategy that suits trading companies because it allows a greater degree of vertical integration and better control of the company's supply chain [7]. Moreover, for the past few years some researchers point out the trend of returning from outsourcing to insourcing business strategy [6]. Accordingly, the subject of this paper is the development of a logistics system in a trading company based on the principles of insourcing.

The logistics system in trading companies must be compatible with the basic structure of the system and defined according to the requirements of flows and users in the market of products and services. Each of the logistics subsystems has its own function, purpose, technology, spatial and economic characteristics, each generates costs and enables certain effects.

On the other hand, subsystems are in strong interaction, i.e. interdependence, and they are all important for the distribution of goods, quality of delivery and the degree of satisfaction of the customer, i.e. the recipient of the goods. In the goods distribution logistics system, there is often a mismatch in changes of the individual subsystems.

The consequences are mainly significant and generate additional costs, which are usually not quantified, but certainly burden the company's financial condition.
This paper presents the scenarios for the development of the logistics system of a trading company and describes the procedure for their evaluation. Each scenario must take into account the interdependencies between the logistics subsystems and enable efficient and effective realization of the future requirements for the procurement and distribution of products, while maintaining the high level of service quality for the client. Since the selection of scenarios depends on several factors, their assessment requires the application of the multi-criteria decision-making (MCDM) methods. A hybrid MCDM model based on a combination of fuzzy AHP (Analytical Hierarchy Process) and fuzzy VIKOR (Višekriterijumska Optimizacija i kompromisno Rešenje) methods is applied in this paper for solving the problem of evaluation and selection of the best scenario for the development of the logistics system of a trading company.

2. CHARACTERISTICS OF THE EXISTING LOGISTICS SYSTEM OF THE COMPANY

The company selected for the case study of the logistics system development scenario selection, developed the logistics network in parallel with the trade network [8]. Since the beginning of the business activities when the company had one warehouse next to the sales facility, they have developed into a system with five regional logistics centers (RLC), one of which stands out as a central one, and dozens of sales facilities, i.e. business units (BU), most of which perform the functions of warehousing, keeping inventory and delivery of goods for customers (wholesale - WS and retail - RT) in the catchment area [8]. However, the existing business volume, market and customer requirements seek for more efficient logistics. On the other hand, expensive city land and new business strategies are moving in the direction of the development of showroom-type BUs, only for the display of goods, without the function of keeping inventories. These facts, along with the planned increase in business volume in the future, will result in a significant increase in requests for the delivery, reception, dispatching and shipping of goods, which requires a significantly more serious approach to the development of the logistics function.

The analysis of supply chains revealed three key members, i.e. primary participants: suppliers (domestic and foreign manufacturers), trading company (RLC and BU) and customers (WS and RT) [8]. In addition to the primary members, the participants who provide support, primarily through the implementation of the transport service for the part of the import flows between the foreign suppliers and RLC and part of the deliveries for the WS customers, were also identified. Among the primary members of the supply chain, three basic levels of distribution have been identified: from the supplier to the RLC, from the RLC to the BU in the immediate surrounding, and from the BU to the customers. In addition, the connections were also identified: domestic manufacturer - BU and RLC - WS customer [8]. In general, business units receive goods from the associated RLC, but in some situations and for some goods, deliveries are made from other RLCs. Delivery of goods to the customer is realized either from the business unit, the associated or central RLC.

The optimal level of inventories is not defined for the entire system, therefore they are defined and monitored separately for every RLC and BU. Part of the inventories is non-current goods that do not have a buyer or has difficulties finding one. This primarily refers to the items that are no longer current or have insufficient quantity, while they are no longer produced or procured. The company operates with a large number of changing suppliers, who change about 10% of the production range annually. The change in the product range also affects the growth of the quantity of non-current goods.

A big problem in the logistics of the trading company are RLCs. They have developed primarily for the functions of warehousing and keeping inventories. These systems generally do not have the possibility of spatial expansion, and their layout is not in line with the warehouse and distribution functions. RLCs mainly meet average requirements, but the problems arise in the periods of more intense requests for the logistics services, primarily the delivery of goods.

The roads within the complex are not adequately arranged and marked, the manipulative space is limited, so the movement of vehicles and handling equipment is extremely difficult. A big, perhaps the biggest problem are the transshipment fronts that are not defined nor dimensioned according to the requirements. In addition, there are no markings of areas, nor the defined flows of vehicles, goods and people, which negatively affects not only the logistics requirements performance efficiency, but also the safety of movement within the centers’ complexes.

The warehousing function in RLC is not completely planned, i.e. designed in accordance with the relevant technological requirements, in spite the fact that these are mainly newer facilities, built with the purpose of disposing and storing the goods. The omissions are of a construction, as well as technological nature. Closed buildings have poor insulation and roofing, and some open warehouses do not have an asphalt-coated surface or it is in poor condition, causing the problems with the drainage of atmospheric water. Receipt and dispatch zones, as the important segments of the distribution logistics, i.e. the delivery of goods,
seem to have been left out in the process of defining the solutions of logistics centers. Their non-existence is one of the main reasons for the inefficiency of the logistics process of delivery of goods in the period of peak requirements.

The warehouse technology is mostly floor-standing, while in some sections the platforms have been set up in order to better utilize the height of the buildings, but without a system for performing the vertical transport. Disposal zones are not marked, so locating the goods depends on the skill of the person in charge for the warehouse facilities. In the part of the closed warehouse facilities, the technology of rack storage of goods is applied, but the arrangement of the zones for the selective pallet racks do not enable optimal use of space. By adjusting the height of the cells according to the classes and frequency of the pallet units’ heights and by applying the adequate handling equipment, such as the narrow aisle forklifts, it is possible to make certain changes to the pallet racking zones, resulting in the increased space utilization and warehouse capacity.

The purpose of the areas in the RLC is not clearly defined, i.e. improvised solutions are applied, and the space is used when needed, without a clear organization of logistics flows and activities. Since there are no defined areas, there is no marking in the logistics complexes, i.e. vertical and horizontal signalization. This situation negatively affects the efficiency of the realization of logistics requirements for the receipt, warehousing and dispatch of the goods, but also the safety of movement.

In addition to the aforementioned problems related to the RLC, in some situations the efficiency of the logistics requirements realization is badly affected by some characteristics of the company’s business. The information system in logistics chains is very bad. The lack of information on the reception of vehicles and goods generates numerous problems, such as: congestion of the transshipment fronts, waiting for the vehicle to be loaded, errors in receipt, dispatch and delivery of goods, etc. Efficient realization of logistics flows requires planning, and planning is not possible without information that precedes the flow of goods.

The absence of information on the reception of goods, large number and frequent changes of the suppliers, large range of products and packaging of goods and large volume of delivery requests, on one side, and inadequate RLC system, unregulated and undefined areas and flows, lack of capacity and adequate marking and tracking system, on the other, makes planning of the logistics processes very difficult, often impossible. Inadequate system of planning requirements and business processes result in great time losses caused by waiting for vehicles to load/unload, delivery delays, delivery errors, but also duplication of transport and transshipment activities.

Development plans, current production trends and market demands impose serious challenges in front of the company’s logistics system. The company’s orientation towards the RT customers imply expansion of the product range, and the wider range usually generates larger inventories. In addition, changes in production are very intense, and will be significantly greater in the future. New technologies and shorter preparation of the production process, justify the release of smaller batches, which in turn affects the growth of the product range and inventories of the goods for sale. On the other hand, with the expansion of the network of showroom-type sales facilities, without keeping inventories, the greater degree of supply centralization is achieved. A centralized supply system implies a reduction in warehousing and inventory costs, but also an increase in the cost of transporting goods. The number of deliveries on a daily basis is increasing, thus generating the requirements for the significantly more efficient implementation of all logistics processes.

3. LOGISTICS SYSTEM DEVELOPMENT SCENARIOS

The selection of the supply model for a sales facility depends on the company’s preference on the distribution with warehouses and inventories (2, Figure 1) or on the distribution without inventories, with shorter retention of the goods at places of transshipment, storage, sorting, order picking, i.e. in logistics centers (3 and 4, Figure 1).

For the supply of large retail models (Source: adapted from [9])

Figure 1 - Trading company supply facilities (Source: adapted from [9])

For the supply of large retail facilities or companies with a larger number of sales facilities, a centralized distribution system prevails. An oversized warehouse creates problems which significantly overpasses the economic viability. The development of flexible logistics systems reduces investments in the construction of large and expensive warehouses, therefore the money can be redirected to the development of logistics centers with an efficient transshipment system.
and faster turnover of goods, which leads to the reduced inventories and more efficient operations. Warehouses without inventories appear in the form of cross docking systems and transit warehouses.

Based on the analysis of the current state of logistics of the trading company, plans for future development, assessment of possible changes in flows and markets, as well as trends in logistics, four scenarios for the development of the logistics system are defined:

- **Sc1**: Scenario of improvement of the existing logistics structure;
- **Sc2**: Scenario of redirection of the logistics flows;
- **Sc3**: Scenario of modified logistics network structure with cross-dock terminals;
- **Sc4**: Scenario of the 3PL leader.

The defined scenarios cover different levels of development of the company’s logistics system, from improving the efficiency of the existing processes (scenario Sc1) and moderate development (scenario Sc2), to the significant changes in the system structure in line with the changes in logistics and regional operations (scenario Sc3 and Sc4).

In addition, the proposed solutions cover a wider range of possible development concepts and allow for a gradual development and transition from one scenario to the next.

**Scenario Sc1**, scenario of improvement of the existing logistics structure. The analysis of the current state of trading company’s logistics revealed a number of problems that can be partially solved, without significant changes in the existing structure of the logistics system (network of storage systems) and supply chains, but with better organization and application of more advanced logistics processes (Figure 2).

Figure 2 - Struktura lanaca snabdevanja – scenario Sc1 (Source: by authors)

Scenario Sc1 implies:
- The existing network with five RLCs, each representing a classic storage system with the function of product accumulation and distribution.
- Retaining the existing strategy of directing most of the flows to the central RLC.
- Definition and arrangement of the order picking and reception-dispatch zones and transshipment fronts in order to make the process of receipt and dispatch of goods more efficient. New layout of receiving and dispatching zones and transshipment fronts.
- Increase of the capacity of the warehouse system and the availability of products, by defining and marking storage zones and introducing new solutions of rack storage technology.
- Introduction of goods marking system, using bar code and RFID (Radio Frequency Identification)
technology, in order to provide accurate information on the implementation of logistics processes in real time.

- Introduction of the support systems for warehouse and transport systems management, WMS (warehouse management system) and TMS (transport management system) systems.
- Improvement of construction solutions in certain centers.
- Change of the fleet structure according to the changes in distribution requirements.

Scenario Sc2, scenario of redirection of the logistics flows. By directing flows to the central RLC, unnecessary additional movements of goods on the way to the customer occur. A strategy to redirect flows in the existing network structure can enable better utilization of the logistics system.

This scenario also implies certain changes in logistics activities and processes, improvement of technologies within the existing structure of distribution centers and implies:

- The existing network with five RLCs, each representing a classic storage system with the function of product accumulation and distribution.
- Change of supply chains and redirection of a significant part of flows from the central RLC to other RLCs, according to the requirements and sales plans.
- Adaptation of the space, capacity and technology of the centers to the new requirements that result from the redirection of flows.
- Definition and arrangement of the order picking and reception-dispatch zones and transshipment fronts in order to make the process of receipt and dispatch of goods more efficient. New layout of receiving and dispatching zones and transshipment fronts.
- Increase of the capacity of the warehouse system and the availability of products, by defining and marking storage zones and introducing new solutions of rack storage technology.
- Introduction of goods marking system, using bar code and RFID technology.
- Introduction of integrated WMS and TMS systems.
- Change of the vehicle fleet structure according to the changes in the supply system and distribution requirements.

Scenario Sc3, scenario of modified logistics network structure with cross-dock terminals. The development of the logistics system under this scenario implies the inclusion of two cross dock (CD) terminals in the function of distribution of goods and the retention of existing centers with classic warehousing and distribution functions. Scenario Sc3 implies:

- Construction of two CD terminals, which should be located in accordance with the delivery flows and the scope of the catchment area requirements. The existing network with five RLCs remains, but the structure and scope of the logistics service requirements are changing. This concept involves a combination of all four mentioned product distribution models.
- Direction of the most intensive flows to the CD terminals.
- Modifications of existing RLC in accordance with the change in the scope and structure of logistics service requests. This certainly implies definition and arrangement of the order picking and reception-dispatch zones and transshipment fronts in order to make the process of receipt and dispatch of goods more efficient. New layout of logistics centers.
- Increase of the capacity of the warehouse system and the availability of products, by defining and marking storage zones and introducing new solutions of rack storage technology.
- Introduction of goods marking system, using bar code and RFID technology.
- Introduction of integrated WMS and TMS systems.
- Change of the vehicle fleet structure according to the changes in the supply system and distribution requirements.

Scenario Sc4, scenario of the 3PL leader. The considered company has a developed logistics network with logistics centers at five locations in Serbia, but also serious plans when it comes to expanding its business to the region. It has a developed warehousing and transport distribution system, and regardless of the problems that have been identified, the company has the opportunity to become a 3PL logistics provider for the third parties. The scenario involves the distribution of goods using two CD terminals while retaining and upgrading existing RLCs with classic warehousing and distribution functions. Scenario Sc4 implies:

- Formation of a special part of the company with the organizational performance of a 3PL provider, which could grow over time into a 4PL logistics service provider.
- Intensive involvement in e-commerce and e-logistics flows.
- Construction of two CD terminals, along with the technological and capacitive improvement of the
existing logistics network, which would be the quality and strength of the new logistics company. This concept would enable the combination of all four mentioned product distribution models.

- Development of a new logistics network. Dominant flows would be directed to the CD terminals according to the requirements of e-logistics, while for the certain categories of goods and users, the flows would go through the modernized existing centers. In this scenario, there might be a need to expand the network, in case the company selects this development path.

- Modifications of the existing RLCs, i.e. the definition and arrangement of the order picking and reception-dispatch zones and transshipment fronts, i.e. definition of the new layout plans, in order to process the reception and dispatch of goods more efficiently.

- Increase of the capacity of the warehouse system and the availability of items by changing the storage technology.

- Introduction of goods marking system, using barcode and RFID technology.

- Introduction of integrated information logistics platforms that will unite all previous advanced WMS and TMS systems.

- Improvement and expansion of the vehicle fleet according to the changes in distribution requirements.

- In case of a higher degree of logistics development, it is possible to form a virtual logistics networks for the product segment which is the basic preference of the company.

4. CRITERIA FOR THE LOGISTICS SCENARIOS EVALUATION

The defined scenarios for the trading company logistics system development can be differentiated in terms of a number of criteria. For their evaluation and ranking, nine criteria, described below, are defined.

- **C₁** - The possibility of developing a modern logistics system. The trading company is also present on the markets of the neighboring countries, so the development of a modern, integrated logistics system could provide a number of business advantages and a competitive position in the entire region. Considering that it already has a developed logistics network in Serbia, despite the observed problems, the company is well on its way to realizing that. Certain changes in the layout of regional logistics centers and application of the appropriate warehousing and handling technologies, identification and tracking systems (scenario Sc₁ and Sc₂), would create conditions for improving the system efficiency, while the network expansion and the inclusion of the CD terminals (scenario Sc₃) would increases the system flexibility and create a good basis for the development of the advanced, integrated logistics solutions that are necessary for the functioning of a 3PL provider (scenario Sc₄).

- **C₂** - The possibility of an efficient response to the growing demand for logistics services. The spatial characteristics of the existing centers do not allow significant expansion and increase of the storage and distribution capacity of the system. Given that the company’s development strategy is aimed at approaching to the end customers and increasing the centralization of the warehousing function, the number of requests for delivery of goods from logistics centers will increase. As the logistics processes of preparation and dispatch of goods are the most critical part of the logistics chains, the development of the system according to the scenario Sc₁ and Sc₂ would limit the possibilities of an efficient response to the growth of the requirements. The expansion of the logistics network and the introduction of the CD terminals would increase the capacity of the system, enable the faster turnover of goods, reduce the handling costs and shorten the delivery times. By focusing the company on the development of a 3PL provider, the capacity problems of the logistics system would almost be non-existent. Finally, the logistics system development variants defined by the scenario Sc₃, and especially by the scenario Sc₄, also have the advantage by this criterion.

- **C₃** - The possibility of implementation. The analyzed logistics scenarios differ significantly in terms of time, speed and complexity of implementation and understanding by the employees. The activities necessary for the development of the system according to the scenario Sc₁ represent the basis for other scenarios, i.e. development variants. Switching from one variant to another can cause resistance and difficulty in accepting a new business model by the employees. Scenarios implying the integration of the CD terminals into the company’s logistics network (Sc₁) and the development of a 3PL provider (Sc₄), despite a number of advantages in terms of system efficiency, require a number of systematic and time-consuming changes. New, advanced systems require a number of researches, projects, discussions, adjustment of procedures and rules, education and training, i.e. application of a series of activities and measures in order to support the establishment of the system. In that sense, the scenario Sc₁ has a
significant advantage according to this criterion, followed by the scenario of redirection of the flows Sc₂, while scenarios Sc₃ and Sc₄ represent much more demanding solutions in terms of this criterion.

- **C₄** - Investments for the logistics system development. Scenarios of the expansion of the logistics network imply the development of two CD terminals (scenario Sc₃), i.e. more modern logistics complexes (scenario Sc₄). Their construction requires significant investments that depend on the location, size and structure of the planned facilities and the technology of the logistics processes operation. On the other side, scenarios that rely on the existing structure of the logistics system (scenarios Sc₁ and Sc₂) also need the investments. Regional logistics centers require certain investments in order to create conditions for more efficient implementation of logistics, warehousing and handling processes and application of the advanced planning and management systems. In addition to the procurement and installation of equipment, it is necessary to repair warehouse facilities (e.g. to improve the facilities' insulation characteristics, repair the roof structure, repair the floor, arrange the areas for receiving and dispatching goods, construct the traffic and handling areas and access roads, etc.). Estimated investments for the modernization of the existing logistics system are 15 to 30% of the value of total investments for the development of the CD terminals, depending on the adopted level of improvement.

- **C₅** – Logistics service quality. The trend of growth of the requirements in terms of logistics service quality parameters (speed, accuracy, reliability, flexibility, etc.) will continue in the future. Systems based on the modern logistics principles, integration and coordination, with the application of new inventory management models and systems for monitoring goods and flows, significantly improve the quality parameters of the logistics service. Scenarios involving the expansion of the logistics network (Sc₃ and Sc₄) enable easier adaptation to the changes or specific needs and allow the shorter system response times. However, an efficient logistics system reduces the impact of the distances from which the goods are being delivered, and the application of the WMS and TMS enables significantly better business performance, therefore the development of a logistics systems under the Sc₁ or Sc₂ scenarios should not be problematic in terms of the service quality.

- **C₆** - Delivery logistics costs. By applying the existing supply concept and directing the flows to the central RLC (scenario Sc₁), an additional transshipment point appears and the costs of delivering the goods to the RLC and BUs increase. In the flow redirecting scenario (scenario Sc₂), goods are mostly delivered directly from the suppliers to the business units and regional logistics centers, which has a direct impact on the reduction of transport costs. Transport costs are especially reduced by the introduction of the CD terminals and development of the logistics system according to the Sc₃ and Sc₄ scenarios, respectively.

- **C₇** – Time losses in inbound-outbound transport. Waiting for a vehicle to load/unload is a major problem of the company's existing logistics system. With the development of the logistics system according to the scenario Sc₁ and the arrangement of the central RLC, primarily its part for receiving and dispatching vehicles and goods, the time losses in the inbound-outbound transport of goods can be significantly reduced or completely eliminated. But still, the problem of unnecessary rides remains, while the spatial limitations of the central RLC represent a limiting factor for the capacity expansion and efficient realization of the future requirements, primarily the shipment of goods and vehicles. By distributing the flows more even and directing them to the other centers (scenario Sc₂), time losses can be significantly reduced, although some of the centers may have major problems in receiving and dispatching the vehicles and goods, even for the existing level of the requirements. With the introduction of the CD terminal (Sc₃) and the modern logistics complex (Sc₄), time losses in inbound-outbound transport can be reduced to a minimum. The effects of the Sc₁ and Sc₄ scenarios in terms of this criterion also depend on many factors, such as the selection of the location, size and structure of the system, technology of the logistics processes realization, etc.

- **C₈** – The number of handling operations. Errors, costs and time of the chains realization increase with the growth of the number of the handling, i.e. transshipment operations, as well as the probability of damage, disintegration and loss of goods/logistics unit. Considering that the number of the handling, transshipment operations is the largest in the system of directing the flows to the central RLC, the scenario Sc₁ is the worst according to this criterion as well. On the other hand, one of the most significant effects of the cross docking system is the elimination of unnecessary handling of goods, therefore the scenarios Sc₃ and Sc₄ have a significant advantage according to this criterion.

- **C₉** – Environmental and safety aspect. Since the environmental and safety effects depend on the
savings in kilometers traveled and the number of handlings in the reception and dispatching of goods, the Sc3 and Sc4 scenarios have an advantage by this criterion too. In addition, the safety of vehicles, equipment and people within the existing logistics centers requires special attention, especially in the centers with a larger volume of work.

5. SCENARIONS EVALUATION

A hybrid model based on the combination of the fuzzy AHP and the fuzzy VIKOR multi-criteria decision-making (MCDM) methods is applied for the evaluation and selection of the most favorable scenario.

The fuzzy AHP method is used to obtain the weights of the criteria for the evaluation of the alternatives (scenarios). The AHP method [10] in general deals with determining the relative importance of criteria in the MCDM problems. AHP decomposes the complex MCDM problem into hierarchically arranged decision-making elements. The hierarchy has at least three levels, the ultimate goal at the top, a number of criteria that affect the alternatives and the alternatives at the bottom. In the general case, based on the problem set in this way, an analysis is performed in order to determine the relative weights of the criteria at each hierarchical level and the values of the alternatives in relation to the criteria. Although the AHP method is a good technique for evaluation and decision-making problems, decision-makers’ assessments of decision-making factors are often inaccurate, vague, and ambiguous due to incomplete information or inability to process them under given conditions.

On the other hand, fuzzy set theory can effectively deal with ambiguity in thinking and expressing decision makers’ preferences. By integrating fuzzy logic into the process of pair wise comparison of the elements, the AHP method becomes more flexible and gives more realistic and accurate results. The fuzzy AHP method [11] has been widely accepted and applied in the literature, either alone or in combination with some other methods, to solve various problems [12, 13, 14, 15, 16, 17, 18, 19].

The fuzzy VIKOR method is applied in the second part of the model to rank the alternatives, i.e. scenarios, and select the most favorable one. The VIKOR method [20] is suitable for solving decision-making problems due to its stability and simplicity in the use of cardinal information. Another advantage is that it takes into account the ranking in relation to the weakest performance according to defined criteria. The method focuses on the ranking and selection of alternatives in relation to numerous, in most cases conflicting and mutually incomparable decision-making criteria and determines a compromise solution to the problem. A compromise solution means an admissible solution that is closest to the ideal, and is considered a compromise because it was reached with mutual concessions. The obtained compromise solution can be accepted by the decision maker because it achieves the majority maximum group utility and minimum individual regret of the opposing parties. A compromise solution can be the basis for negotiations because it involves the preferences of decision makers through the weight of criteria. The VIKOR method has been extended in the fuzzy environment [21] to solve the problem of uncertainty in expressing the preferences of decision makers and has since been used alone or in combination with other methods to solve various problems [22, 23, 24, 25, 26, 27].

For criteria comparison, in the process of determining their weights using the fuzzy AHP method, as well as for the alternatives evaluation, in the process of selecting the most favorable one using the fuzzy VIKOR method, a fuzzy linguistic scale that can be converted into triangular fuzzy numbers is used (Table 1).

### Table 1. Linguistic evaluations and fuzzy scale

<table>
<thead>
<tr>
<th>Linguistic term</th>
<th>Abbreviation</th>
<th>Fuzzy scale</th>
</tr>
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<tbody>
<tr>
<td>None</td>
<td>N</td>
<td>(0.1, 0.1, 1)</td>
</tr>
<tr>
<td>Very low</td>
<td>VL</td>
<td>(0.1, 1, 2)</td>
</tr>
<tr>
<td>Low</td>
<td>L</td>
<td>(1, 2, 3)</td>
</tr>
<tr>
<td>Fairly low</td>
<td>FL</td>
<td>(2, 3, 4)</td>
</tr>
<tr>
<td>More or less low</td>
<td>ML</td>
<td>(3, 4, 5)</td>
</tr>
<tr>
<td>Medium</td>
<td>M</td>
<td>(4, 5, 6)</td>
</tr>
<tr>
<td>More or less high</td>
<td>MH</td>
<td>(5, 6, 7)</td>
</tr>
<tr>
<td>Fairly high</td>
<td>FH</td>
<td>(6, 7, 8)</td>
</tr>
<tr>
<td>High</td>
<td>H</td>
<td>(7, 8, 9)</td>
</tr>
<tr>
<td>Very high</td>
<td>VH</td>
<td>(8, 9, 10)</td>
</tr>
<tr>
<td>Extremely high</td>
<td>EH</td>
<td>(9, 10, 10)</td>
</tr>
</tbody>
</table>

Various procedures have been developed to solve the fuzzy AHP method, and in this study the logarithmic fuzzy preference programming (LFPP) method is used [28], which approximates the fuzzy evaluations \( \tilde{a}_{ij} \) from the matrix \( \tilde{A} \), which represents a comparison of criterion \( i \) in relation to criterion \( j \), by the following relation:

\[
\ln \tilde{a}_{ij} \approx (\ln l_{ij}, \ln m_{ij}, \ln u_{ij}), i, j = 1, ..., n \quad (1)
\]

where \( n \) is the total number of criteria.

For obtaining the criteria priority values \( w_i \) it is necessary to solve the following nonlinear priority model:

\[
\min J = (1 - \lambda)^2 + M \sum_{i=1}^{n} \sum_{j=i+1}^{n} (\delta_{ij}^2 + \eta_{ij}^2) / 2
\]

subject to:

\[
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\[ x_i - x_j - \lambda \ln \left( \frac{m_{ij}}{l_{ij}} \right) + \delta_{ij} \geq \ln l_{ij} \quad i = 1, ..., n; j = i + 1, ..., n \]  

(3)

where, \( x_i = \ln w_i \) for \( i = 1, ..., n \), and \( M \) is the large enough constant such as \( M = 10^3 \). \( \delta_{ij} \) and \( \eta_{ij} \) are nonnegative deviation variables introduced to avoid \( \lambda \) from taking a negative value.

It is desirable that these values are as small as possible, while they have to meet the following inequalities:

\[ \ln w_i - \ln w_j - \lambda \ln \left( \frac{m_{ij}}{l_{ij}} \right) + \delta_{ij} \geq \ln l_{ij} \quad i = 1, ..., n; j = i + 1, ..., n \]  

(7)

\[ -\ln w_i + \ln w_j - \lambda \ln \left( \frac{u_{ij}}{m_{ij}} \right) + \eta_{ij} \geq -\ln u_{ij} \quad i = 1, ..., n; j = i + 1, ..., n \]  

(8)

Let \( x_i'(i = 1, ..., n) \) be the optimal solution to the nonlinear model. The normalized priorities for fuzzy pairwise comparison matrix \( \tilde{A} = (\tilde{a}_{ij})_{n \times n} \) can then be obtained as:

\[ w_i^* = \frac{\exp(x_i')}{\sum_{i=1}^{n} \exp(x_i')} \quad i = 1, ..., n \]  

(9)

where \( \exp() \) is the exponential function, namely, \( \exp(x_i') = e^{x_i'} \) for \( i = 1, ..., n \).

After obtaining the criteria weights, the scenarios are evaluated using the fuzzy VIKOR method. First, it is necessary to construct the fuzzy performance matrix (\( \tilde{B} \)) whose elements \( \tilde{b}_{ki} = (l_{ki}, m_{ki}, u_{ki}) \) represent the triangular fuzzy evaluations of the alternatives \( S^i \), \( k = 1, ..., m \), in relation to the criterion \( C_i \), \( i = 1, ..., n \).

Ideal \( \tilde{f}^*_i = (l_i^*, m_i^*, u_i^*) \) and nadir \( \tilde{f}^*_i = (l_i^*, m_i^*, u_i^*) \) values of all criteria functions, which represent the evaluations of the initiatives in relation to the criteria are obtained as \( \tilde{f}_i^* = \max_k \tilde{f}_{ki} \), \( \tilde{f}_i^* = \min_k \tilde{f}_{ki} \).

Afterwards, the normalized fuzzy differences are calculated as follows:

\[ \tilde{d}_{ki} = \frac{\tilde{f}_{ki} \ominus \tilde{f}_{ki}}{u_i - l_i} \]  

(10)

Maximum group utility \( \tilde{S}_k \) and minimum individual regret \( \tilde{R}_k \) are then calculated using the following equations:

\[ \tilde{S}_k = \sum_{i=1}^{n} w_i^* \ominus \tilde{d}_{ki} \]  

(11)

\[ \tilde{R}_k = \max_{l} w_l^* \ominus \tilde{d}_{kl} \]  

(12)

Based on these values, the overall distances of the alternatives from the ideal solution \( \tilde{Q}_k \) are calculated in the following manner:

\[ \tilde{Q}_k = \frac{\tilde{S}_k \ominus \tilde{S}_k^*}{\sum_{i=1}^{n} \tilde{S}_i^* - \tilde{S}_i^*} \ominus (1 - v) \frac{\tilde{R}_k \ominus \tilde{R}_k^*}{\sum_{l=1}^{n} \tilde{R}_l^* - \tilde{R}_l^*} \]  

(13)

where \( \tilde{S}_* = \min_k \tilde{S}_k \), \( \tilde{S}_u = \max_k \tilde{S}_k \), \( \tilde{R}_* = \min_k \tilde{R}_k \), and \( \tilde{R}_u = \max_k \tilde{R}_k \). The value \( v \) is introduced as a weight for the strategy of „the majority of criteria” (or „the maximum group utility”), whereas \( l - v \) is the weight of the individual regret. Defuzzification of the values \( \tilde{S}_k \), \( \tilde{R}_k \) and \( \tilde{Q}_k \) is then performed by using the equation [29]:

\[ \text{crisp}(P) = (\alpha + 4\beta + \gamma)/6 \]  

(14)

where \( \text{crisp}(P) \) is the defuzzified value of any triangular fuzzy number \( \tilde{P} = (\alpha, \beta, \gamma) \).

Ranking of scenarios is performed by the increasing \( \text{crisp} \) values. The results are three ranking lists \( \{S\}_1 \), \( \{S\}_R \) and \( \{S\}_Q \) obtained by the values \( \text{crisp}(S) \), \( \text{crisp}(R) \) and \( \text{crisp}(Q) \), respectively. Proposal as a compromise solution the scenario \( S^{(1)} \) which is the best ranked by the value of \( Q \), if the following two conditions are satisfied: Co.1. „Acceptable Advantage” \( \text{Adv} \geq DQ \) where \( \text{Adv} = \frac{\left[ Q(S^{(2)}) - Q(S^{(1)}) \right]}{\left[ Q(S^{(2)}) + Q(S^{(1)}) \right]} \)

is the advantage rate of the scenario \( S^{(1)} \) in relation to the scenario ranked as the second \( S^{(2)} \) in the list \( \{S\}_Q \), and \( DQ = 1/(o - l) \) is the threshold from which the advantage rate (Adv) has to be higher. Co.2. „Acceptable stability in decision making”**: The scenario \( S^{(1)} \) must also be the best ranked by \( S \) or/and \( R \). If one of the conditions is not satisfied, then a set of compromise solutions is proposed, which consists of: CS1. The scenarios \( S^{(1)} \) and \( S^{(2)} \) if only the condition Co.2 is not satisfied, or CS2. The scenarios \( S^{(1)}, S^{(2)}, ..., S^{(o)} \) if the condition Co.1 is not satisfied; \( S^{(o)} \) is determined by the relation:

\[ Q(S^{(o)}) - Q(S^{(1)})]/[Q(S^{(2)}) - Q(S^{(1)})] < DQ \]

for maximum \( S \) – the total number of the scenarios (the positions of these scenarios are „in closeness,”), where \( S^{(o)} \) is the last ranked element in relation to \( Q \) and \( S^{(1)} \) is the scenario with the highest index value.

According to the described methodology for the defined problem structure, the causal connections between the elements (criteria) are first established by applying the fuzzy AHP method. The comparison of the criteria is performed using the linguistic scale, after which the linguistic values are converted into triangular fuzzy numbers using the relations given in Table 1. The values of the criteria comparison are presented in Table 2.
Table 2. Fuzzy comparison of the criteria

<table>
<thead>
<tr>
<th></th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
<th>C₅</th>
<th>C₆</th>
<th>C₇</th>
<th>C₈</th>
<th>C₉</th>
</tr>
</thead>
<tbody>
<tr>
<td>C₁</td>
<td>/</td>
<td>(0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>1, 2, 3)</td>
<td>2, 3, 4)</td>
<td>3, 4, 5)</td>
<td>4, 5, 6)</td>
<td>5, 6, 7)</td>
<td>6, 7, 8)</td>
</tr>
<tr>
<td>C₂</td>
<td>0.5, 1, 1.10</td>
<td>/</td>
<td>1, 2, 3)</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 10)</td>
<td>1, 2, 10)</td>
<td>/</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 10)</td>
</tr>
<tr>
<td>C₃</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 0.1, 1)</td>
<td>1, 2, 3)</td>
<td>2, 3, 4)</td>
<td>3, 4, 5)</td>
<td>5, 6, 7)</td>
<td>5, 6, 7)</td>
</tr>
<tr>
<td>C₄</td>
<td>0.3, 0.5, 1</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>/</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>2, 3, 4)</td>
<td>3, 4, 5)</td>
<td>4, 5, 6)</td>
</tr>
<tr>
<td>C₅</td>
<td>0.25, 0.3, 0.5</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>2, 3, 4)</td>
<td>3, 4, 5)</td>
<td>3, 4, 5)</td>
</tr>
<tr>
<td>C₆</td>
<td>0.2, 0.25, 0.3</td>
<td>0.25, 0.3, 0.5</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>2, 3, 4)</td>
<td>2, 3, 4)</td>
</tr>
<tr>
<td>C₇</td>
<td>0.17, 0.2, 0.25</td>
<td>0.2, 0.25, 0.3</td>
<td>0.25, 0.3, 0.5</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 1, 2)</td>
<td>1, 2, 3)</td>
<td>1, 2, 3)</td>
</tr>
<tr>
<td>C₈</td>
<td>0.14, 0.17, 0.2</td>
<td>0.17, 0.2, 0.25</td>
<td>0.14, 0.17, 0.12</td>
<td>0.2, 0.25, 0.3</td>
<td>0.25, 0.3, 0.5</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 1, 2)</td>
</tr>
<tr>
<td>C₉</td>
<td>0.12, 0.14, 0.17</td>
<td>0.14, 0.17, 0.12</td>
<td>0.17, 0.2, 0.25</td>
<td>0.25, 0.3, 0.5</td>
<td>0.25, 0.3, 0.5</td>
<td>0.3, 0.5, 1</td>
<td>0.5, 1, 10</td>
<td>/</td>
<td>0.1, 1, 2)</td>
</tr>
</tbody>
</table>

By applying the described methodology for solving the fuzzy AHP method, the following criteria weights are obtained: \( w_{i} = (0.179, 0.342, 0.171, 0.109, 0.085, 0.046, 0.030, 0.023, 0.015) \). After obtaining the criteria weights, the evaluation of the scenarios in relation to the criteria is performed. Scenarios are also evaluated with linguistic expressions which were then converted into triangular fuzzy numbers using the relations given in Table 1. These values are given in Table 3. By applying the described methodology for solving the fuzzy VIKOR method, the values presented in Table 4 are obtained.

Table 3. Evaluation matrix of scenarios in relation to the criteria

<table>
<thead>
<tr>
<th></th>
<th>C₁</th>
<th>C₂</th>
<th>C₃</th>
<th>C₄</th>
<th>C₅</th>
<th>C₆</th>
<th>C₇</th>
<th>C₈</th>
<th>C₉</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sc₁</td>
<td>(3, 4, 5)</td>
<td>(1, 2, 3)</td>
<td>(9, 10, 10)</td>
<td>(8, 9, 10)</td>
<td>(3, 4, 5)</td>
<td>(2, 3, 4)</td>
<td>(1, 2, 3)</td>
<td>(1, 2, 3)</td>
<td>(1, 2, 3)</td>
</tr>
<tr>
<td>Sc₂</td>
<td>(5, 6, 7)</td>
<td>(3, 4, 5)</td>
<td>(8, 9, 10)</td>
<td>(7, 8, 9)</td>
<td>(5, 6, 7)</td>
<td>(5, 6, 7)</td>
<td>(5, 6, 7)</td>
<td>(4, 5, 6)</td>
<td>(5, 6, 7)</td>
</tr>
<tr>
<td>Sc₃</td>
<td>(7, 8, 9)</td>
<td>(6, 7, 8)</td>
<td>(5, 6, 7)</td>
<td>(3, 4, 5)</td>
<td>(8, 9, 10)</td>
<td>(8, 9, 10)</td>
<td>(6, 7, 8)</td>
<td>(6, 7, 8)</td>
<td>(6, 7, 8)</td>
</tr>
<tr>
<td>Sc₄</td>
<td>(8, 9, 10)</td>
<td>(9, 10, 10)</td>
<td>(1, 2, 3)</td>
<td>(1, 2, 3)</td>
<td>(9, 10, 10)</td>
<td>(9, 10, 10)</td>
<td>(8, 9, 10)</td>
<td>(8, 9, 10)</td>
<td>(8, 9, 10)</td>
</tr>
</tbody>
</table>

Table 4. Results of the fuzzy VIKOR method application

<table>
<thead>
<tr>
<th></th>
<th>Sc₁</th>
<th>Sc₂</th>
<th>Sc₃</th>
<th>Sc₄</th>
</tr>
</thead>
<tbody>
<tr>
<td>S'</td>
<td>0.376</td>
<td>0.192</td>
<td>0.069</td>
<td>0.052</td>
</tr>
<tr>
<td>S''</td>
<td>0.598</td>
<td>0.432</td>
<td>0.309</td>
<td>0.237</td>
</tr>
<tr>
<td>S'''</td>
<td>0.763</td>
<td>0.598</td>
<td>0.475</td>
<td>0.402</td>
</tr>
<tr>
<td>Crisp S</td>
<td>0.883</td>
<td>0.630</td>
<td>0.445</td>
<td>0.350</td>
</tr>
<tr>
<td>Rang</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>R'</td>
<td>0.228</td>
<td>0.152</td>
<td>0.038</td>
<td>0.114</td>
</tr>
<tr>
<td>R''</td>
<td>0.304</td>
<td>0.228</td>
<td>0.114</td>
<td>0.152</td>
</tr>
<tr>
<td>R'''</td>
<td>0.342</td>
<td>0.266</td>
<td>0.152</td>
<td>0.171</td>
</tr>
<tr>
<td>Crisp R</td>
<td>0.446</td>
<td>0.332</td>
<td>0.161</td>
<td>0.223</td>
</tr>
<tr>
<td>Rang</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Q'</td>
<td>0.092</td>
<td>-0.167</td>
<td>-0.434</td>
<td>-0.335</td>
</tr>
<tr>
<td>Q''</td>
<td>0.568</td>
<td>0.324</td>
<td>0.058</td>
<td>0.056</td>
</tr>
<tr>
<td>Q'''</td>
<td>1.000</td>
<td>0.756</td>
<td>0.489</td>
<td>0.460</td>
</tr>
<tr>
<td>Crisp Q</td>
<td>0.841</td>
<td>0.472</td>
<td>0.071</td>
<td>0.088</td>
</tr>
<tr>
<td>Rang</td>
<td>4</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

As the alternative Sc₁ is ranked as the best one according to \( Q \), and by taking into account that both conditions Co₁ (Adv = 1.000 ≥ DQ = 0.333) and Co₂ (Sc₁ is also ranked as the best alternative according to R) are satisfied, it has been selected as the compromise solution, i.e. as the best scenario for the development of the company’s logistics system.
6. CONCLUSION

The selection of a scenario for the development of a trading company's logistics system is a complex process that requires consideration of a number of criteria. Therefore, in this paper, a hybrid MCDM model, which combines the fuzzy AHP method for determining the criteria weights and the fuzzy VIKOR method for ranking and selection of scenarios, is used to solve the problem. The model is developed in the fuzzy environment since the fuzzy logic can adequately deal with the ambiguity and vagueness in the assessments of the decision makers. The scenario Sc3, which implies a changed structure of the logistics network with cross dock terminals, is selected as the most favorable solution. Although this scenario was not assessed as the most favorable one by any of the considered criteria, it is selected as a compromise solution because it provides a good balance between the possibilities for the development of a modern logistics system, the efficient response to the growth in the demand for services, and implementation possibilities. In addition, it offers a high level of service quality with acceptable investments, logistics costs, time losses and the number of handlings.

The described methodology for solving the observed problem is universally applicable, while the model itself could, after certain adjustments, be applied to solve similar problems in other trading companies. In the future research, new scenarios could be formed, while the set of criteria could be expanded, which would depend on the characteristics of the companies themselves and the market conditions in which they operate. In addition, the MCDM model itself could be extended with methods that enable the unification of the assessments of a larger number of decision makers, if there is a need for it.

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REZIME

OCENA SCENARIJA RAZVOJA LOGISTIČKOG SISTEMA – STUDIJA SLUČAJA TRGOVAČKE KOMPANIJE

U radu je prikazan postupak izbora scenarija razvoja logističkog sistema u kompaniji sa razvijenom trgovačkom i logističkom mrežom, ali i značajnim problemima u snabdevanju. U cilju rešavanja postojećih problema logistike, ali i odgovora na buduće zahteve i planove poslovanja, definisana su četiri scenarija razvoja logističkog sistema. Svaki od scenarija ima određene karakteristike koje u upoređenoj analizi mogu biti prednosti ili manje. S obzirom da izbor scenarija razvoja zavisi od više faktora, njihovo rangiranje u pogledu različitih kriterijuma zahteva primenu metoda višekriterijumskog odlučivanja (VKO). Za rešavanje problema primenjen je hibridni model koji se zasniva na kombinaciji fuzzy AHP (Analytical Hierarchy Process) i fuzzy VIKOR (Višekriterijumska Optimizacija i kompromisno Rešenje) metoda.

Ključne reči: logistički sistem, scenario razvoja, višekriterijumsko odlučivanje, fuzzy AHP, fuzzy VIKOR