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Investigating cross-docking criteria for raw materials with hybrid MCDM

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Abstract
The cross-docking process involves unloading raw materials from incoming vehicles and immediately loading them onto outgoing vehicles. This can greatly improve supply chain operations and expedite transportation to the factory. By minimizing warehouse storage expenses, space requirements, and inventory management, the process can be streamlined effectively. In industries where production profiles need to be responsive to market demands, the location of the cross-docking facility and transportation planning are crucial. This article aims to investigate the criteria for selecting a cross-docking location, using a case study of Arta Profile Company in Ardabil. The research population includes all industrial engineers and production planners in the company, with 10 industry experts selected for this study. The analytic network process (ANP) and grey complex proportional assessment (COPRAS-G) methods were used to compare and prioritize cross-docking locations. Additionally, the fuzzy DEMATEL method was used to determine the strength of connections between different locations. The COPRAS-G approach helps decision-makers make informed decisions by evaluating different options and their importance. The industry experts identified 28 criteria for this study. The results from the network analysis method showed that the most important criterion is the vehicle routing problem (VRP), with a value of 0.46. According to the ANP technique, strategic decision-making is the best option. The fuzzy DEMATEL method revealed that distribution centers are the most important factor, followed by reduced delivery/distribution operations, and finally, the cost of late or early delivery.

Keywords
Cross docking, raw materials, locating, ANP, Fuzzy DEMATEL, COPRAS-G.

Introduction

Since the early 2000s, big online stores like Amazon and Walmart have been using cross-docking to be better than their competition. This means they can have less stuff in storage and spend less on shipping. It also helps them offer next-day delivery to customers. Also, companies like Nexus Logistics and Menlo Logistics offer services to help customers purchase, store, ship, and deliver products. In real life, as more people live in cities and more packages are being delivered, it costs more to deliver things. But even with that, the number of people wanting things delivered to their homes is going up (Goodarzi et al., 2020).

Cross docking is a good way to manage how products move in a supply chain. It helps save money by reducing the need for storage and making transportation more efficient. It's a smart strategy for businesses and important for the international trade of raw materials (Li et al., 2022; Fang et al., 2022). In the research about where to put things, deciding where to put distribution centres and warehouses and how to divide them up for customers is called strategic planning for three to five years. In addition, planning and choosing routes for vehicles are part of short-term decisions that need to be made within a few days to a year. Of course, making these two important decisions together will improve the whole system because they depend on each other (Mousavi et al., 2014). Picking the right place in distribution centres (DC) to keep costs low is an important decision. Making smart choices about where things are placed and how they get there can save a company much money and make it run more smoothly. This is because the cost of moving things around is a big part of a company's expenses. In traditional location problems, we assume that all facilities are good and then find the best places for them in the perfect situation (Xie et al., 2015). In real life, buildings can have many unexpected problems that can make them not work properly. Not having the right location could make it more expensive to transport customers from their usual place to a farther one (Berman et al., 2007; Snyder et al.; 2005).

Cross-docks were made to help manage supply chains better. Cross docking is a distribution strategy where items are moved directly from one transportation method to another without going to a warehouse. This usually happens within a day or a night. By reducing the volume of material transfers and warehouse costs, the cross-dock can be more efficient than the traditional warehouse due to eliminating storage and order preparation activities. These advantages have caused the cross-dock to become an attractive logistics system in such a way that it can even lead to a competitive advantage for companies (Kazemi et al., 2021). A cross-dock makes things move faster, uses fewer vehicles, and lowers how much we have to keep in stock. The main reason for having a cross dock in most companies is to gather different products on pallets, put them together with the right destination, and deliver them to the customer's or production plant as needed. A cross-dock can make distribution networks smaller by combining and moving big loads of cargo instead of delivering small loads in many shipments. The aim is to use full truckloads as much as possible to make transporting goods cheaper and run the docks smoothly with the right coordination of incoming and outgoing trucks (Ladier et al., 2015).

Finding cross-dock centres (CDCs) and assigning them to customers is an important decision that should be made for 3 to 5 years. Alternatively, decisions about when and where transportation will be used are short-term choices that need to be made daily or yearly. Clearly, combining these two key decisions while maintaining their independence leads to improving the entire network design system. Past research has found that when companies combine where they put their buildings with how they plan their transportation routes, it saves them money in the long run (Mousavi et al., 2014). So, combining how to move things with where to put centres can help save money and make the supply chain work better. So, this is one of the things needed to combine decisions in supply chain network design (Kazemi et al., 2021).

The need for good services and the demands of shoppers are making it tough for stores to compete. More shops are opening, and new ways of doing business have come up for modern sellers. So, it's hard to spend less money while making the service better. Many stores now buy their products from one central place instead of buying from different places. Picking the right location in DC to reduce the cost of opening, running, and shipping is an important choice. Improving where things are sent and how they get there in the delivery system can save a lot of money and make everything run more smoothly because shipping costs make up a big part of a company's expenses (Yu et al., 2021). In a place where customers don't like to wait and the competition isn't so tough, the supply chain has to move fast and still keep prices low. A cross-dock is a method used in logistics to lower inventory costs and make the movement of goods faster while also reducing the time it takes for transportation. At a pallet dock, stuff is taken off trucks, organized, and then sent out again. Cross docks make us think about how to make them work better, whether it's in planning, daily operations, or long-term strategy (Ladier et al., 2015).

- Locating

Locating studies are considered one of the key measures in building industrial or service units (investment plan), and paying attention to this matter plays a significant role in the victory of an industrial unit. Its importance is because the principled or unprincipled and incorrect choice of the place to create a plan can affect it from other aspects of the market, such as technical, financial, and economic aspects. Locating is traditionally interested in problems where the weights of servers and their availability are known with certainty, but in reality, accurate estimation of all parameters is not possible; therefore, location models with uncertainty have been investigated, and some of their modes have been defined and studied (Wang et al., 2009). In these models, the servers may fail, and the assigned clients of the servers have to get service from the working servers. These problems based on this feature are called backup location problems (Wang et al., 2009). The problems of locating the median and centre of support were first investigated by (Wang et al., 2009). They respectively presented pattern rhythms with O (n) and O(nlogn) times for two problems.

The location problem is about where to put things, and the routing problem is about how to get them there. Combining them into one problem gives better but not perfect solutions. Location routing problem (LRP) is a type of problem where you have to figure out the best routes for vehicles and the best locations for facilities at the same time(Zarandi et al., 2011). LRP is used in many different areas like delivering food and drinks, newspapers, taking out the garbage, delivering bills, military work, managing used oil, organizing for natural disasters, exchanging batteries, delivering packages, and distributing different things people buy (Manzour-al-Ajdad et al., 2012). In recent years, the LRP has been getting more attention. Many researchers have suggested different ways to solve this problem. For example (Nagy et al., 2007; Lopes et al., 2016), in traditional facility location problems, we assume that all facilities are dependable, and we figure out the best places to put them in this perfect situation. However, in reality, places may have a lot of unplanned problems that can stop them from working properly.

Studies on LRP are divided into three parts: the issues it addresses, how it can be used in real life, and problems related to its rhythmic patterns (Drexl et al., 2015). Many problems are considered typical LRPs. Designing location routing models can help save much energy in DCs. These models can find cheap and practical ways to solve the problem while also considering where to put facilities and how to use vehicles. This situation finds the lowest actual cost and can be shown as an LRP. Min and others. In 1998, a basic explanation of LRP sub-problems and their relation was given. (Nagy et al., 2007) used LRP in actual situations. Because it's important to know how LRP is used in real life, the programs are sorted into five groups, as shown in Table 1 (Yu et al., 2021).

Tab. 1. Location routing problem

Authors	Application
(Karaoglan et al., 2015; Wang ety al 2014, Chen et al ., 2007)	**Reduce** operations
(Watson-Gandy et al., 1973; Madsen et al., 1983; Jacobsen et al., 1980; Semet et al., 1993; Bruns et al., 2000; Lin et al., 2002, Gunnarsson er al 2006)	Delivery of goods/distribution
(Ahmadi et al., 2013; Caballero et al., 2007; Nambiar et al 1981, Dong er asl., 2015)	Management policy
(Alomore et al., 2007)	Environmental issues

- *Hub location*

Hubs are where many things come together in networks that have multiple paths for things to travel along. Combining things makes it cheaper to transport them between hubs. Hubbing also helps to decrease the number of links required for routing flows to their destination. The hub location problem is about finding where the centre of the hub is and where other places are in relation to it based on what we need and how everything is set up. One person can choose where to put the hubs based on things like how much of something is being moved, how much it costs to move things between different places, how much it costs to move things between hubs, how many things can be sent to each hub, and the shape of the hub network. In single allocation mode, all the traffic from one place to another goes through a central hub. Alternatively, when multiple things are to be distributed, you can use different ways to send them to different places. Lüer-Villagra et al. (2013) and Mahmutoğulları et al. (2015) suggested a problem about where to put hubs in the transportation industry that would compete with each other. Lin et al. (2013) used a problem about where to put the centre of a bicycle-sharing system when they designed it.

Another type of network design that considers vehicles at hubs is called the hub location routing problem. Think of the hubs in this problem as a warehouse with many rules, like only a certain number of doors to leave from. We have to schedule when trucks leave to deliver products to customers, so the biggest problem is figuring out the right timing and order. However, in the hub location routing problem, the most important decision is finding the best vehicle routes between the satellite locations. In hub location problems, goods from each source are sent to hubs before being sent to their final destination. "First, the destinations are divided among the nodes, and then each assigned node distributes the demand for those destinations simultaneously (Mousavi et al., 2017).

- *Cross-docking*

In a place where businesses don't compete against each other, and customers don't like to wait, the way products are made and delivered needs to be quick, efficient and cheap. Cross-docking helps save money on inventory and speed up the shipping process. At a cross-dock, goods are taken off incoming trucks, organized, sent out, and put onto outgoing trucks. The number of products in storage is reduced because the items don't stay at the cross-dock for more than 24 hours (Ladier et al., 2015). Cross-docking is a strategy used by many companies, like retail stores and shipping companies, to help with logistics. However, cross-docking is a method used by many transportation businesses. It can be costly because it eliminates the need for storage and picking orders. Several studies have looked into this approach (Van Belle et al., 2012).

A cross-dock is when products from different suppliers are received at one place and then put together to be sent to the same final destination. The main idea of a cross-dock is to move shipments from incoming trucks to outgoing trucks without storing them in a warehouse in between. This practice can be used for different reasons: combining shipments, delivering faster, saving money, and more. It even seems that the role of interconnection in the industry is increasing. Transhipment is when cargo from different places is combined and moved to another location without being handled much or stored in between. A cross-dock can save money by combining distribution networks and using full truckload (FTL) shipments instead of direct and less-than-truckload (LTL) deliveries. Inbound pallets are usually delivered to the transit hub with LTL shipping, while outbound pallets are shipped with FTL. The aim is to reduce how much it costs to transport goods and ensure they get to where they need to go by using FTL shipments. A good system of cross docks and careful planning of incoming and outgoing vehicles is very important for things to work well (Ladier et al., 2015). The cross-dock corresponds to the objectives of complete supply chain management (SCM): a smaller or larger volume of visible inventory that is delivered faster and more frequently. Several studies in the domestic literature have highlighted the numerous advantages of cross-docking in comparison to traditional distribution centres and point-to-point delivery. These advantages, which may be interconnected, have been discussed by various authors, such as Boysen et al. (2010) and Van Belle et al. (2012). The rising trend of companies embracing the cross-dock strategy can be credited to the escalating demand for supply chain optimization. A cross-dock refers to a logistics procedure in which products are transported from a supplier to a manufacturing plant through inbound trucks (IT) and subsequently to a cross-docking terminal (CDT) (see Figure 1) (Theophilus et al., 2019).

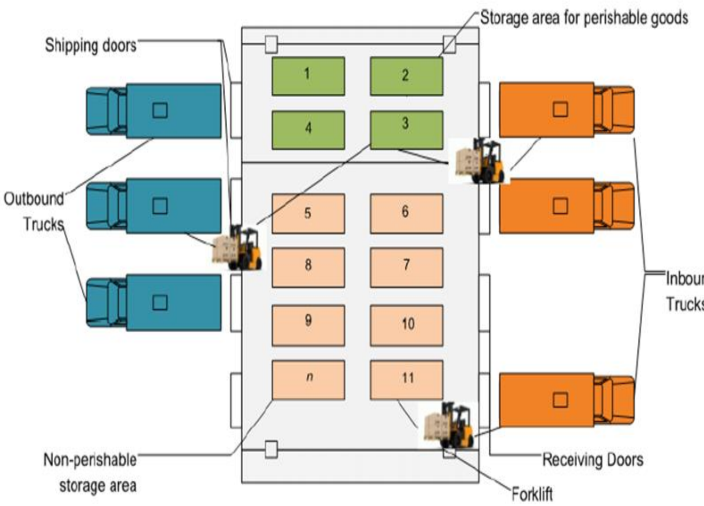

Fig. 1: Cross dock terminal

Figure 1 illustrates the components of a standard docking terminal, which includes a series of receiving doors for the docking of IT for service, a separate set of transhipment doors for the docking of OT for service, and a designated area for sorting and storage. The sorting/storage area is specifically designed to accommodate temperature-controlled storage, commonly utilized for perishable products.

- *Performance Measurement*

Multiple indicators can be used to measure the performance of cross-dock operations. This section presents a comprehensive list of potential performance measures, some of which can also serve as elements in the objective function for optimization problems. The objectives mentioned by (Boysen et al., 2010) in their list, which primarily focuses on the truck scheduling problem, are included here. Additionally, we have added other objectives that are derived from worker training or specific subversive operations.

Inventory level

Cross-docking aims to have less inventory, so it's important to track how many products are stored and the highest number of products stored in a certain period.

- *Working hours*

The people working at a logistics platform are often the biggest expense, especially when they have to do things by hand. So, the total hours needed to finish the job is an important sign.

- *Balanced workload*

Even though it's hard to measure exactly, each worker should get a fair amount of work hours.

- *Travel distance*

Another crucial factor to consider is the cumulative distance covered by all the items within the dock, as a lengthier distance would result in a greater amount of time required for the worker to accomplish their duties.

- *Density*

Concentrating all loading and unloading activities in a single location to reduce travel distance may result in congestion and hinder the efficiency of the entire process. Consequently, the density of tasks in a specific area can significantly impact performance; however, quantifying this effect lacks a straightforward measurement method.

- *Total loading or unloading time*

[35] propose that in order to expedite the return of goods and promptly release the doors, it is essential to minimize the total completion times of the trucks. Another potential objective is to minimize the time spent by outbound trucks at the outbound docks. Similarly, monitoring the total time spent by inbound trucks at the entrance docks can serve as a significant indicator that the utilization rate of the entrance doors is high.

- *The total time the product stays*

To achieve optimal product turnover, tracking the total duration that all products spend within the cross dock is essential. This serves as a significant metric for monitoring efficiency and effectiveness in maximizing product flow.

- *Truck processing time deviation*

It is crucial to guarantee the fulfilment of arrival time deadlines by accurately identifying whether incoming or outgoing trucks are arriving early or late. The designated indicator monitors instances where the truck needs to arrive ahead of schedule or depart at the designated time due to the inability to commence unloading or complete loading as planned.

- *Using the door*

The utilization rate of the entrance or exit door serves as a reliable indicator for determining the total loading or unloading time.

- *Unloaded products*

One additional metric that can be tracked is the count of unsuccessful orders, which refers to the quantity of products that fail to be shipped, resulting in potential profit loss.

- *Program length or time interval*.

To expedite the completion of a task, it is crucial to assess the overall duration of the program or schedule. This can be achieved by calculating the time difference between the commencement of the first operation and the conclusion of the last operation, which is likely to be the final truckload.

- *Preventive costs*

It is important to consider the cost of transporting the trucks between the doors and the yard if pre-handling is permitted.

- *The number of interactions*

A pallet undergoes a single interaction when it is directly moved from the incoming truck to the outgoing truck. Each interaction incurs a cost associated with the labour involved, making the average or overall number of interactions a potential performance metric (Ladier et al., 2015).

- *Cross dock location*

In today's competitive landscape, the identification of suitable platforms is of significant importance in the realm of logistics management for efficient distribution systems (Ladier et al., 2015). The smooth flow of products, starting from suppliers or providers, passing through transit distribution centres, and reaching retailers or customers, plays a crucial role in logistics networks (Mousavi et al., 2014). The strategic decisions of locating cross docks and assigning them to customers are typically made for a period of 3 to 5 years. Conversely, decisions regarding the scheduling and routing of transportation means fall within the short-term or operational tactical realm, requiring a daily or less than a year time frame. Clearly, combining these two key decisions while maintaining their independence leads to improving the entire network design system. Previous research has demonstrated that incorporating facility location choices with equipment routing and transportation scheduling in daily operations can result in long-term cost savings. The strategic inclusion of cross-dock systems in the design of distribution networks within a supply chain plays a crucial role in achieving this objective. A strategy is needed to decide on the location of these loads. Also, this issue cannot be used separately from the decision regarding the way to compensate goods in these networks (Van Belle et al., 2012). In 2003, Song and Song conducted an initial investigation on the positioning of cross docks. As a result of this study, several articles were written, and they focused especially on the issue of the location of CDCs. Among these articles, the following can be mentioned (Sung et al., 2003; Musa et al., 2010; Sung et al., 2017). In recent years, many articles have studied the issue of cross-dock location along with other issues, such as scheduling and routing. Here one can refer to the works of (Mousavi et al., 2013; Mousavi et al., 2017; Xie et al., 2015). During the process of long-term planning, one of the initial choices to be taken into account is the placement of one or multiple CDCs within the framework of cross-dock distribution networks. The location problem of CDCs was first addressed by ((Sung et al., 2003), who researched this matter. Their study revolved around the transportation of products from suppliers to retailers through a cross-dock distribution centre. The cross-dock distribution centre can be selected based on the available options and their associated fixed costs (Mousavi et al., 2014). In the study by Javanfaret al. (2017), they successfully addressed a location-routing problem within a three-level supply chain. This supply chain consisted of suppliers, transit warehouses, and customers, specifically focusing on the perishable food distribution and distribution industry. The researchers approached the problem in a multi-product mode, where vehicles were assumed to be homogeneous. They presented a comprehensive mixed integer nonlinear integrated mathematical model to tackle this complex problem. Notably, their model allowed for multiple pickups and deliveries while also considering limitations on transportation capacity and product availability for the vehicles. In the study of Eslaminia et al. (2020), they focused on routing using electric vehicles and considered various constraints such as load volume limitation and limited battery capacity. They developed a mixed integer programming model to minimize the total distance travelled for product distribution. They employed the simulated annealing (SA) technique to solve this model. On the other hand, Qiu et al. (2018) proposed a mixed integer linear programming model for the multi-vehicle and multi-product routing problem. This model incorporated setup costs and served as an extension of the multi-vehicle and single-product routing problem model. Additionally, it also acted as a generalization of the multi-vehicle inventory routing model. Notably, this model considered multiple products and involved making production decisions in a specific order.

Many companies faced many problems in supplying their raw materials for production. Failure to reach the status of raw materials would increase the costs of production companies or even lead to the closure of these units. Due to the lack of manufactured goods, more demand was seen in the market. In this case, the producers faced many problems in the field of production and delivery of goods to customers. On the other hand, locating suitable docks for unloading and loading raw materials was one of the most important challenges in the production units. The cross-dock has proven to be an effective method for managing inventory flow (Taleghani et al., 2018). By directly transferring goods from receiving doors to dock doors, the cross-dock minimizes the time that COVID-19 affected goods spend in the facility. After a brief inspection to ensure that imported goods and raw materials are free from the virus, they are promptly cleared and sent to production units. Essentially, the cross-dock strategy streamlines operations by eliminating the need for traditional warehouse inventory management. It allows raw materials or imported goods to be sorted, unloaded and then loaded onto vehicles through a consolidation process (Gelareh et al., 2020).

This research consists of 4 parts. The first part was related to introducing cross-dock location, which was described. In the next, material and methods, results and conclusions have been discussed respectively.

Material and Methods

The data collection tool of this research was a questionnaire. According to Saaty (1994), 10 people from Arta Ardabil's profile company were considered to be the statistical population. The process of identifying the criteria for the placement of cross docks was conducted after a thorough study and review of the company's experts' opinions, as well as an extensive review and analysis of research literature in the field. A questionnaire was then used to prioritize the dimensions of cross-dock location, and the data was analyzed using the ANP method. In order to analyze and understand the impact of various factors on the location of cross docks, the data collection process utilized the Fuzzy DEMATEL and COPRAS-G methods. These methods were employed to compare and identify the relationships between different factors and determine their severity in influencing the location of cross docks. These techniques enabled a comprehensive understanding of the factors and their effects on cross-dock locations. A research framework is shown in Figure 2.

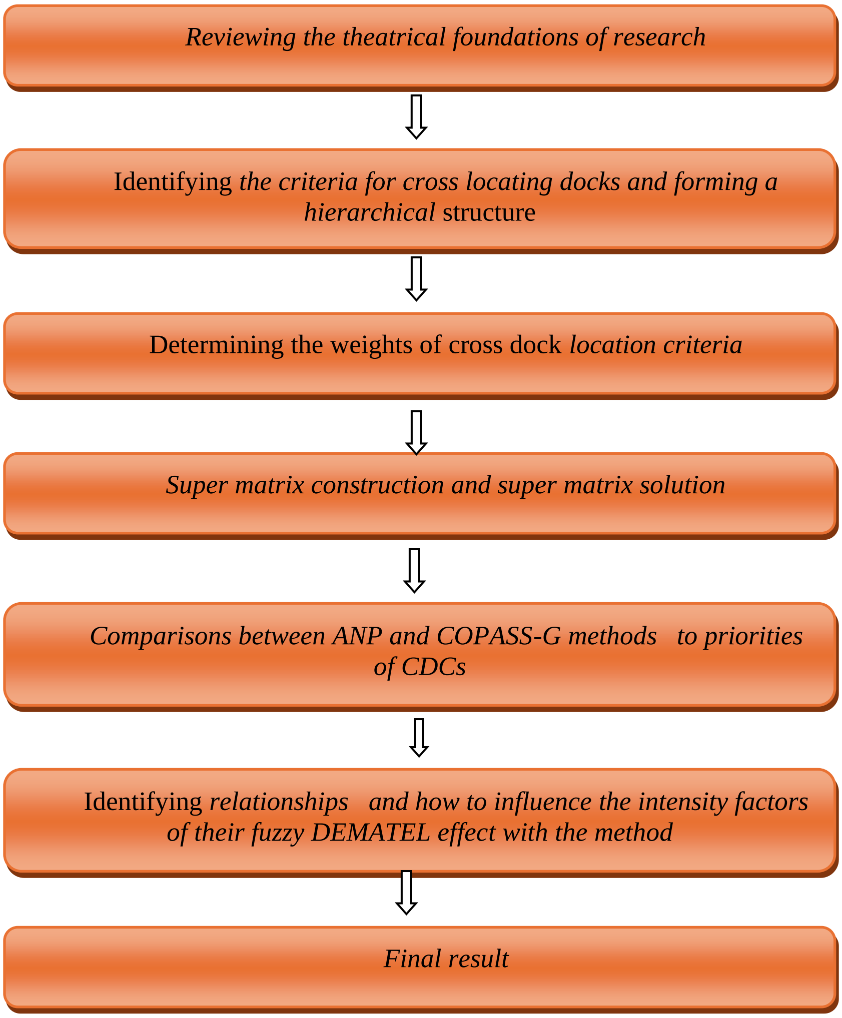

Fig. 2. Research framework

- *Network Analysis*

The ANP is an extension of the analytical hierarchy process (AHP) that considers the interdependencies between elements in a hierarchy. In certain decision-making scenarios, it is impossible to structure the problem hierarchically due to interactions and dependencies among higher-level elements. In such cases, ANP represents the lower-level elements using a network instead of a traditional hierarchy, as explained by Saaty (2006). ANP is a comprehensive decision-making technique through which the output follows the criterion. AHP is the starting point in ANP. Identification of priorities is similar and consistent in both methods. In AHP, it is used as a pairwise comparison. ANP consists of 4 steps:

- *Hierarchical construction and structure of the problem*

Problem structure in any hierarchy requires levels such as goals, perspectives, criteria, and choices. Hierarchies, goal comparisons, levels of elements, and relationships between elements can be identified by examining decision makers' brainstorming ideas or other appropriate methods such as literature review.

- *Determining the weight of criteria and views*

During this phase, the committee responsible for decision-making generates a set of paired comparisons that pertain to the significance of criteria and perspectives. In these comparisons, the index 1-9 is used. At this level, the weights of criteria and views are provided using a specific super matrix vector and used in the supermatrix. Saaty (2006) introduced consistency rate (CR) through pairwise matrix comparison. If the value of CR ≤ 0.01, the consistency of the paired matrix comparison is acceptable.

$$W_i = \frac{1}{\lambda_{max}} \sum_{i=1}^{n} a_{ij} w_j \qquad 1,2, \ldots n \qquad (1)$$

λ_{max}: Largest value of special vector

a_{ij}: Pair of matrix comparison

CR $=\frac{CI}{RI}$

CI = Compatibility Index = $\frac{\lambda_{max}-n}{n-1}$

RI= Random Index

- *Construction and separation of the supermatrix*

The idea of a supermatrix bears resemblance to that of a Markov chain process. The second step uses the criteria, views, and weights to calculate the supermatrix column.

$$\mathbf{W} = \begin{bmatrix} W_{11} & W_{12} \cdots & W_{1N} \\ W_{21} & W_{22} & W_{21} \\ W_{N1} & W_{N2} & W_{NN} \end{bmatrix} \quad (2)$$

The ultimate choice for every component within each subgroup is determined by employing an hourly rationale that relies on Markov processes.

$$\boldsymbol{W_c} = \lim_{l\to\infty} \boldsymbol{W^{2l+1}} \quad (3)$$

The convergence of the elements in the supermatrix leads to a singular value, which is then replicated across all rows of the matrix. This enables the prioritization of comparison and ordering choices within each row. Ultimately, the supermatrix is obtained by performing a multiplication operation on itself. Until the values of the rows of the super matrix converge with the same value for each of the columns of the matrix, we call this result the bounded matrix.

- *Choosing the best option*

Due to the limitedness of the matrix and the weight of the options in relation to the criteria, we can integrate the total weight of each option. According to the priority of the weights, we rank the options.

- *Fuzzy DEMATEL*

The purpose of its application is to assess causal connections. This particular combination is employed due to the imprecise and subjective nature of DEMATEL when relying on human judgment. Instead of using real numbers, interval sets are utilized in fuzzy set theory. Linguistic terms are transformed into fuzzy numbers. The suggested approach is advantageous in uncovering relationships between factors and ranking criteria, considering the type of relationships and the extent of impact from each criterion. The analysis of the fuzzy DEMATEL method can be summarized as follows (Wu, 2007)

- *The first step involves defining the criteria for evaluation*

This is crucial in order to have a clear understanding of what needs to be assessed and measured.

- *Once the evaluation criteria are defined*

A group of experts who possess the necessary knowledge and experience about the problem at hand is selected. These experts will then evaluate the relationship and impact between different factors using pairwise comparisons.

- *To address the ambiguity that may arise from human evaluations,*

A fuzzy linguistic scale is introduced. This scale, specifically the linguistic variable "influence," consists of five levels and is used to quantify the impact of factors. The levels include no influence, very little influence, little influence, high influence, and very high influence.

- *In order to facilitate group decision-making, scale items suggested by (*Maity, 2012) *are used.*

These items correspond to the linguistic terms mentioned earlier and are assigned fuzzy numbers, as detailed in Table 2.

Tab. 2. Cross dock location criteria along with abbreviations

Abbreviation	The main dimensions	Abbreviation	The main dimensions
D1	distribution centers	D16	reduce inventory costs
D2	Reduction of delivery/distribution operations	D17	Total loading or unloading time
D3	Design delivery/collection routes from individual warehouses at low cost	D18	Total product shelf life
D4	Simultaneous delivery	D19	Truck process time deviation
D5	Dependence on travel time	D20	number of palette touches

D6	Traffic density during peak hours	D21	Program length or time interval of loaded products
D7	Transportation discount factor between hubs	D22	Timing and routing of vehicles
D8	Single/Multiple Allocation Strategy	D23	Distribution Centers
D9	Hub network structure (star network)	D24	Finding the best location
D10	Number of exit doors	D25	Best timing of vehicle routing
D11	The amount of flow and the cost of transportation between the delivery node	D26	the allocation at the loading door
D12	Increasing the flow of goods	D27	Order preparation and delivery
D13	Shortening the shipping cycle	D28	Late and early costs
D14	Shorter delivery time		
D15	Temporary storage capacity		

An initial direct correlation matrix is then obtained through pairwise comparison. The initial fuzzy direct relationship matrix, denoted as $\boldsymbol{Z^k}$, is developed by representing the fuzzy pairwise influence relationships between the components in an n×n matrix. Here, k represents the number of experts involved. The direct relationship matrix, $\boldsymbol{Z^k}$, is a non-negative n×n matrix, where Zij represents the direct effect of factor i on factor j. When i = j, the diagonal elements are marked as $\boldsymbol{Z^k}_{ij} = 0$ for simplicity.

- *Finally, the D matrix is transformed into a normalized fuzzy direct relation matrix using specific expressions.*

$$D=\frac{z^k}{max\sum_{\substack{j=1\\ 1\le j\le n}}^{n} z_{ij}},i,j=1,2,\ \dots,n \tag{4}$$

- *In the sixth step of the process, the total relation matrix T is computed using a specific expression.*

This expression involves the use of the identity matrix I, which represents a square matrix of size n × n. It is important to note that the upper and lower values are calculated separately in this computation:

This process allows for a more comprehensive understanding of the direct fuzzy relation represented by the Z matrix.

$$\mathbf{T}=[t_{ij}] \qquad i, j= 1,2, \dots \tag{5}$$

$$r_i=\sum_{1\le\ j\ \le n} t_{ij} \qquad \forall i \tag{6}$$

$$c_j=\sum_{1\le\ j\ \le n} t_{ij} \qquad \forall j \tag{7}$$

- *A causal diagram is created with the horizontal axis representing the sum of r_j and c_j, and the vertical axis represents the difference between r_i and c_j.*

The horizontal axis, known as "saliency," indicates the level of importance of the factor, while the vertical axis, known as "correlation," represents the degree of influence. If $\boldsymbol{r_j}$ - $\boldsymbol{c_j}$ is on the positive axis, it signifies that the agent is in the cause group, whereas if it is on the negative axis, it indicates that the factor is in the effect group. Causal diagrams are valuable as they simplify the complex relationships between factors and provide a comprehensible structural model, offering insights for problem-solving. Table 3 shows the linguistic variables for the pairwise comparison.

Tab. 3. Fuzzy spectrum for pairwise comparisons

Verbal variable	Definitive equivalent	Fuzzy equivalent
Effect less	0	(0,0,0.25)
Low impact	1	(0,0.25,0.5)
Medium impact	2	(0.25,0.5,0.75)
High impact	3	(0.5,0.75,1)
Very high impact	4	(0.75,1,1)

- COPRAS-G

Applying the grey system theory allows for converting crisp values to grey numbers, which is crucial in the real-time MCDM process where decision-makers' judgments may be based on incomplete information. The grey relational grade model is particularly effective in handling discrete data, enabling decision-makers to describe their judgments using white, black, and grey numbers (Maity, 2012). On the other hand, COPRAS-G is a newly developed approach in the MCDM process that evaluates alternatives based on attribute values expressed in an interval. This approach is mathematically logical and useful for processing incomplete information, aiming to enhance efficiency and accuracy in the decision-making process. By analyzing different alternatives and estimating their significance and utility, COPRAS-G provides a percentage-based measure of the degree to which one alternative is considered better or worse than others. This approach also incorporates market value estimation and gathers diverse recommendations, distinguishing it from other MCDM approaches. With its ability to handle uncertainty, subjectivity, and imprecise data, COPRAS-G empowers decision-makers to make more accurate decisions (Van Belle et al., 012).

-ANP Analysis

First, in order to clarify the issue regarding the design of the ANP network as shown in Figure 3, the following steps have been taken:

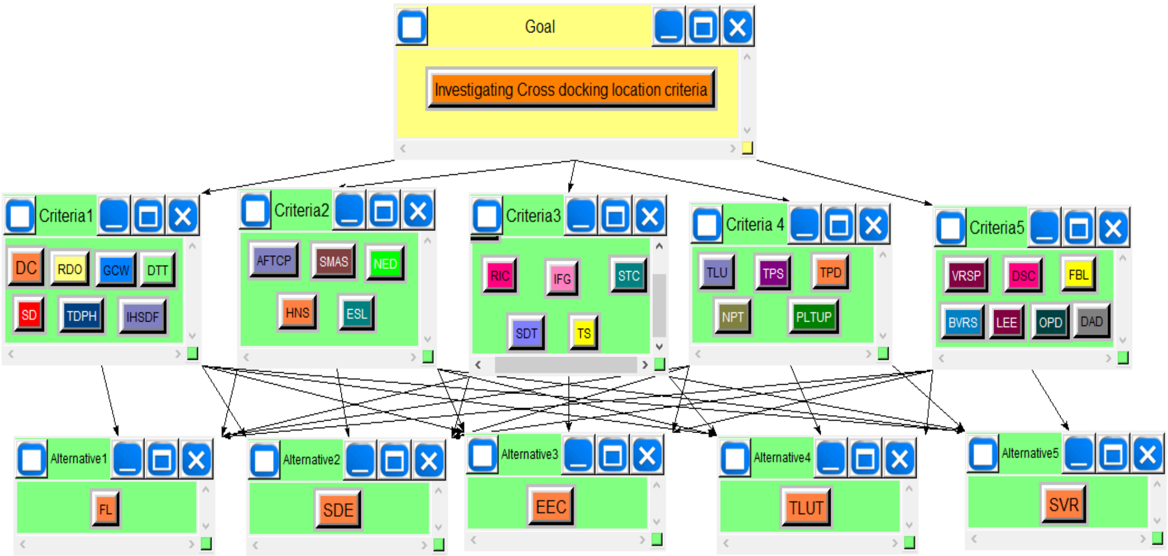

Fig. 3: ANP network

First, the comparison of decision criteria is done as follows.

- *The dimensions of the cross-dock locating*

Vehicle routing, location routing, hub location, performance measurement, and cross-docking routing, according to Figure 4, can be seen that the consistency rate is less than 0.1, so the inconsistency between cross dock location dimensions does not occur. In this diagram, the dimension of the VRP has a value of 0.34 compared to the rest of the dimensions, and it shows that this dimension is of great importance in Arta Profile Company.

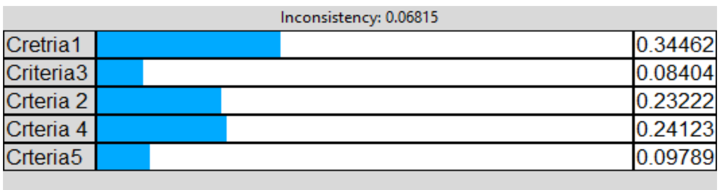

Fig. 4. Comparison of decision dimensions

- *Preference charts of decision criteria*

Distribution centres (DC), simultaneous delivery (SD), travel time dependence (DTT), inter-hub shipping discount factor (IHSDF), design of delivery/collection routes from individual low-cost warehouses (GCW), reduction delivery/distribution operations (DDO), traffic congestion during peak hours (TDPH).

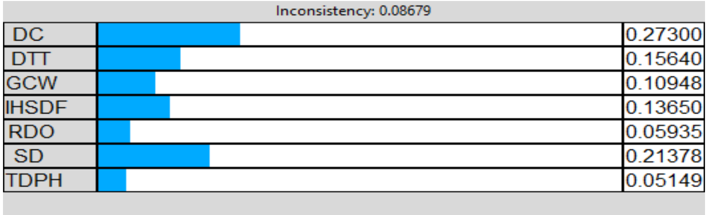

Fig. 5. Comparison of the preference of decision criteria according to the dimensions of the VRP

According to Figure 5, it can be seen that the consistency rate is less than 0.1, so there is no inconsistency between the preferences of decision criteria in the dimensions of the VRP. In this diagram, considering the dimensions of the VRP, the first criterion (DC) of distribution centres has the highest value with a value of 0.273 compared to the rest of the criteria, and it shows that this criterion for the company is more important than other criteria.

- *The priority of decision criteria according to the dimensions of location routing*

The number of flows and the cost of transportation between pairs of company nodes (AFTCP), service level (competitive hub location of the company) (ELS), the structure of the hub network (star network) of the company (HNS), the number of exit doors (NED), strategy allocation (single or multiple allocations (SMAS).

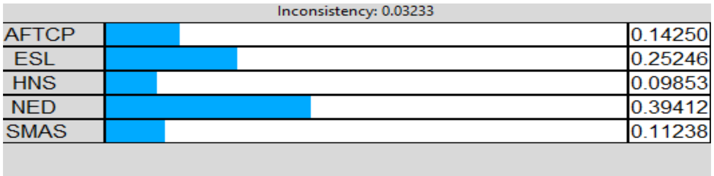

Fig. 6. Comparison of the preference of decision criteria according to the dimensions of location routing

According to Figure 6, it can be seen that the consistency rate is less than 0.1, so there is no inconsistency between the preferences of decision criteria in the dimensions of location routing. In this diagram, taking into account the location routing, the fourth criterion (NED) of the number of exit doors has the highest value compared to the rest of the criteria, with a value of 0.39412.

- *The priority of decision criteria according to the dimensions of the hub location*

Reducing company inventory costs (RIC), shorter delivery time (SDT), shorter transportation cycle (STC), and temporary storage capacity (TS).

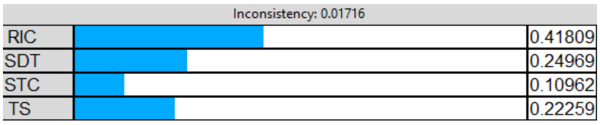

Fig. 7. Comparison of the preference of decision criteria according to the dimensions of hub location

According to Figure 7, it can be seen that the consistency rate is less than 0.1, so there is no inconsistency between the preferences of decision criteria in locating the hub. In this chart, considering the dimensions of the hub location, the first criterion (RIC) of reducing the company's inventory costs with a value of 0.41809 has the highest value compared to the rest of the criteria.

- *The preference of decision criteria according to the dimensions of measuring the performance of passing load*

Number of pallet touches (NPT), program length or interval of unloaded products (PLTUP), total load or unload time (TLU), total processing/truck process deviation time (TPD), and total product shelf time (TPS).

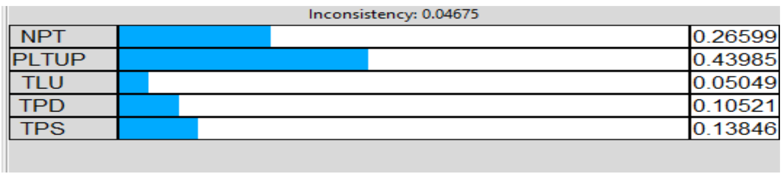

Fig. 8. Comparison of the preference of decision criteria according to the performance measurement of passing load

According to Figure 8, it can be seen that the consistency rate is less than 0.1, so there is no inconsistency between the preferences of decision criteria in the dimensions of cross-dock evaluation. In this diagram, considering the dimensions of performance evaluation of the transit loader, the second criterion (PLTUP) program length or time waste of unloaded products with a value of 0.43985 has been assigned the highest value compared to the rest of the criteria.

- *The preference of decision criteria according to the dimensions of the cross-dock location*

Best vehicle routing scheduling (BVRS), order preparation and delivery (DAD), distribution centres (DSC), delivery and allocation at loader door (FBL), late and early costs (LEE), finding the best location (OPD), vehicle scheduling and routing problem (VRSP).

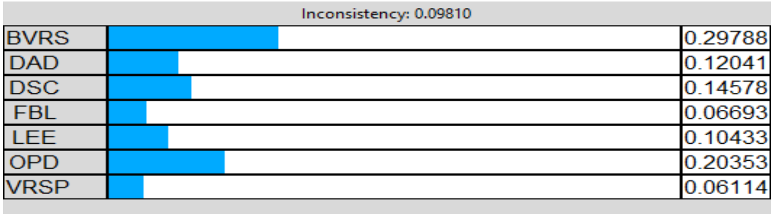

Fig. 9: Comparison of the preference of decision criteria according to the dimensions of cross-dock location

According to Figure 9, it can be seen that the consistency rate is less than 0.1, so there is no inconsistency between the preferences of decision criteria in the dimensions of cross-dock location. In this diagram, taking into consideration the cross-dock location dimensions, the first criterion (BVRS) is the best vehicle routing schedule with a value of 0.29788 compared to the rest of the criteria.

- *The final preference of cross-dock location criteria according to each of the 5 dimensions:*

Total loading and unloading time (AL1), economies of scale, facility location (AL2), strategic decision-making (AL3), transportation scheduling (AL4), and facility location (AL5). The sum of the calculations performed through pairwise comparisons and using the ANP technique according to figures 10 to 14 are shown.

According to the first criterion and Figure 10, if the company wants to use the best option for the location of the cross-dock, the best option is the total loading and unloading time, and the options for saving scale, facility location, decision strategic selection and scheduling of transportation means will be placed in the next selection categories respectively. According to Figure 11 and the second criterion of location routing, if the company wants to use the best option for the location of transit cargo, the best option is the economy of scale and commitment of the company, and the options of total loading and unloading time, equipment scheduling transportation, strategic decision-making and facility location will be in the next selection categories respectively. According to the third criterion and Figure 12, if the company wants to use the best option for the location of the passing load, with the best option, it is a strategic decision and the total options of loading and unloading time, facility location, saving on the total scale. Loading and unloading time will be in the next selection categories, respectively. Suppose the company wants to use the best option for the location of the cross-docking according to the fourth criterion and Figure 13. In that case, the best option is the economy of scale and the options for the location of facilities, scheduling of transportation means, strategic decision making and the total loading and unloading time will be placed in the next selection categories, respectively. According to the fifth criterion, if the company wants to use the best option for the location of transit cargo, according to Figure 14, the best option is strategic decision-making and the options of total loading and unloading time, scheduling of transportation and location and the facilities will be placed in the next selection categories respectively.

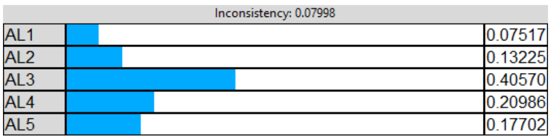

Fig. 11. Preference of the best option for choosing the location of the cross-docking according to the location routing.

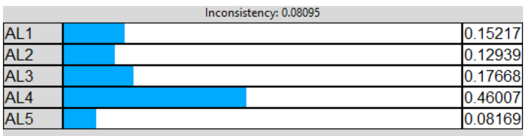

Fig. 10. Preference of the best option for choosing the location of the cross-docking according to the vehicle routing

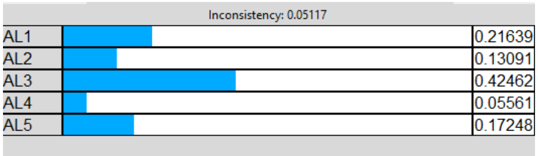

Fig. 13. Preference of the best option for choosing the location of the cross-docking according to the measuring the performance of the cross-dock

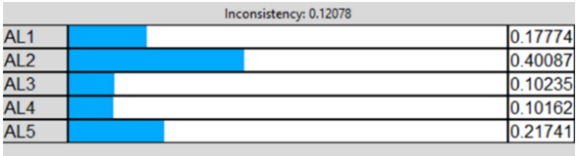

Fig. 2. Preference of the best cross-docking location option according to the hub location

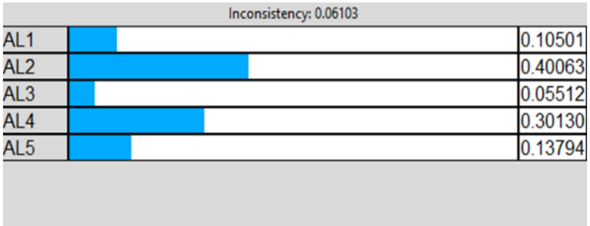

Fig. 14. Preference of the best option for choosing the location of the cross-docking according to the transit cargo

The final preference is to choose the best transit load location option according to 5 dimensions (vehicle routing, location routing, hub location, transit load performance measurement and transit load location).

According to the sum of the calculations made through pairwise comparisons and using the ANP (Fig 15), strategic decision-making is chosen as the best option.

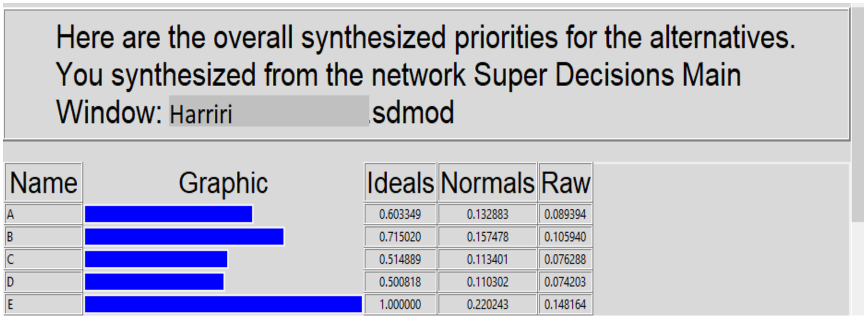

Fig. 15. Selection of the best option for locating the transit load in the decision network

- *Fuzzy DEAMTEL method*
- *To determine the relationship pattern among a set of criteria, an n×n matrix is initially created.*

Each element in the matrix represents the impact of a criterion in a row on the criteria in the corresponding column and is represented as a fuzzy number. If multiple individuals provide their perspectives, each informant is required to fill in the existing matrix. Subsequently, the average of the comments is calculated and used to construct the direct correlation matrix **z**.

$$\mathbf{z} = \begin{bmatrix} 0 & \cdots & \tilde{z}_{n1} \\ \vdots & \ddots & \vdots \\ \tilde{z}_{1n} & \cdots & 0 \end{bmatrix} \quad (8)$$

Table 4 is a part of the direct correlation matrix that shows the same pairwise comparisons of the informants. If several experts were used in the evaluation, the following matrix is the average of all the experts. The number of criteria is 28; due to the limitation, only 4 criteria are given here.

Tab. 4. Direct correlation matrix

	Criterion 1 (Distribution centres)	Criterion 2 (reduction of delivery/distribution operations)	Criterion 3 (designing delivery/collection routes for individual warehouses)	Criterion 4 (simultaneous delivery)
Criterion1(Distribution centers)	(0.000,0.000,0.000)	(0.125,0.250,0.500)	(0.150,0.350,0.600)	(0.150,0.325,0.525)
Criterion 2 (reduction of delivery/distribution operations)	(0.125,0.250,0.500)	(0.000,0.000,0.000)	(0.050,0.275,0.525)	(0.100,0.225,0.475)
Criterion3(designing delivery/collection routes for individual warehouses)	(0.150,0.375,0.625)	(0.050,0.225,0.450)	(0.000,0.000,0.000)	(0.250,0.450,0.675)
Criterion 4 (simultaneous delivery)	(0.125,0.300,0.525)	(0.150,0.325,0.575)	(0.225,0.425,0.650)	(0.000,0.000,0.000)

Also, the verbal range used in the model is given in the Table 5.

Tab. 5. Verbal spectrum

Code	Verbal expression	L	M	U
1	Effect less	0	0	0.25
2	Very low impact	0	0.25	0.5
3	Low impact	0.25	0.5	0.75
4	High impact	0.5	0.75	1
5	Very high impact	0.75	1	1

- *Normalize the fuzzy direct correlation matrix*

The fuzzy direct correlation matrix is normalized using the following relation.

$$\tilde{x}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \quad (9)$$

That

$$r = max_{\top}(i,j) \left\{ \max_i \sum_{j=1}^{n} u_{ij}, \max_j \sum_{i=1}^{n} u_{ij} \right\} i,j \in \{1,2,3,\dots,n\} \quad (10)$$

- *Calculation of the fuzzy matrix of the complete connection*

The fuzzy matrix of the total relationships is generated in this step, following the specified relationship.

$$\tilde{T} = \lim_{k\to\infty} min(\tilde{x}^1 \oplus \dots \tilde{x}^2 \oplus \dots . \tilde{x}^k) \quad (11)$$

The total relationship matrix in each domain is represented by a fuzzy number $\tilde{t}i_j = (l_{ij}'', m_{ij}'', u_{ij}'')$ which varies accordingly calculated as follows:

$$[l_{ij}''] = x_i \times (I- x_i)-1$$
$$[m_{ij}''] = x_i \times (I- x_m)-1$$
$$[u_{ij}''] = x_i \times (I- x_u)-1 \quad (12)$$

To put it differently, the initial step involves calculating the inverse of the normal matrix. Subsequently, we proceed by subtracting this inverse from the I matrix. Lastly, we multiply the normal matrix by the resultant matrix obtained from the subtraction.

- *Defuzzifying the values of the complete correlation matrix*

For defuzzification, Opricovic and Tzeng (2004) and the bell method have been used.
The steps are as follows:

$$l_{ij}^n = \frac{l_{ij}^t}{\Delta_{min}^{max}} \quad (13)$$

$$m_{ij}^n = \frac{l_{ij}^t - \min l_{ij}^t}{\Delta_{min}^{max}} \quad (14)$$

$$u_{ij}^{n} = \frac{u_{ij}^{t}}{\Delta \frac{max}{min}} \quad (15)$$

So that:

$$\Delta \frac{max}{min} = \max u_{ij}^{t} - \min ul_{ij}^{t} \quad (16)$$

Calculation of upper and lower limits of normal values:

$$l_{ij}^{s} = m_{ij}^{s} \ / \ (1+m_{ij}^{n} - l_{ij}^{n}) \quad (17)$$
$$l_{ij}^{n} = m_{ij}^{n} \ / \ (1+m_{ij}^{n} - l_{ij}^{n}) \quad (18)$$
$$u_{ij}^{n} = u_{ij}^{n} \ / \ (1+u_{ij}^{n} - l_{ij}^{n}) \quad (19)$$

The output of *cfcs* rhythm pattern is a matrix with definite values. Calculation of total normalized definitive values:

$$x_{ij} = \frac{[l_{ij}^{s}\left(1-l_{ij}^{s}\right)+u_{ij}^{s} \times u_{ij}^{s}]}{[1-u_{ij}^{n}+u_{ij}^{n}]} \quad (20)$$

- *Threshold calculation*

The complete correlation matrix is thoroughly examined to identify any values that are lower than the mean. Once these values are determined, they are set to zero using a specific relationship. It is important to note that in this process, the causal relationship is not considered.

$$TS = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m} V_{ij}}{m \times n} \quad (21)$$

$$U_{ij} = \begin{cases} V_{ij} & V_{ij \geq TS} \\ 0 & thers \end{cases} \quad (22)$$

The Table 6 shows the complete correlation matrix removed from the threshold (TS). Based on the table below, causal relationships between elements are drawn. The TS value in this research is equal to 0.0620.

Tab. 6. Complete deterministic matrix with the elimination of lower threshold values

	Criterion 1 (Distribution centres)	Criterion 2 (reduction of delivery/distribution operations)	Criterion 3 (designing delivery/collection routes for individual warehouses)	Criterion 4 (simultaneous delivery)
Criterion1(Distribution centers)	0	0	0.156	0.153
Criterion2(reduction of delivery/distribution operations)	0	0	0	0
Criterion3(designing delivery/collection routes for individual warehouses)	0.153	0	0	0.158
Criterion4(simultaneous delivery)	0	0	0.154	0

- *We proceed to obtain the final output and construct a causal diagram.*

To achieve this, we need to calculate the sum of the rows and columns in the **T** matrix. The sum of the rows, denoted as D, and the sum of the columns, denoted as R, can be obtained using the formulas provided.

$$D=\sum_{j=1}^{n} T_{ij} \quad (23)$$

$$R = \sum_{j=1}^{n} \tilde{T}_{ij} \quad (24)$$

The values of D+R and D-R, which represent the level of interaction and the impact of the factors, are obtained based on the information provided by D and R. The resulting data is then presented in the Table 7.

Tab. 7. Final output

Criteria		D-R	D+R	D	R
C1	Distribution centers	0.109	8.536	4.322	4.213
C2	Reduction of delivery/distribution operations	0.051	8.123	4.087	4.036
C3	Designing delivery/collection routes of individual warehouses	-0.019	8.493	4.237	4.256
C4	Simultaneous delivery	-0.107	8.333	4.113	4.22
C5	Dependence on travel time	-0.223	8.223	4	4.223
C6	Traffic density during peak hours	-0.042	8.391	4.174	4.217
C7	Discount factor for transportation between hubs	0.076	8.456	4.266	4.19
C8	Single/multiple allocation strategy	-0.185	8.03	3.923	4.108
C9	Hub network structure/star network	-0.019	8.469	4.225	4.244
C10	Number of exit doors	-0.002	8.838	4.418	4.42
C11	Amount of transport flow between nodes	0.24	8.019	4.129	3.889
C12	Increasing the flow of goods	-0.127	8.335	4.104	4.231
C13	Shortening the transportation cycle	-0.049	8.619	4.285	4.334
C14	Shorter delivery time	-0.064	8.411	4.174	4.237
C15	Temporary storage capacity	-0.009	8.797	4.394	4.403
C16	Reduction of inventory costs	-0.03	8.922	4.446	4.476
C17	Total loading/unloading time	0.074	8.446	4.26	4.186
C18	Shelf life of the product	0.005	8.764	4.385	4.379
C19	Truck process deviation	-0.18	8.787	4.304	4.483
C20	The number of palette touches	-0.006	8.724	4.359	4.365
C21	Program length or product scheduling interval	0.032	8.285	4.159	4.126
C22	Scheduling and routing of transportation means	-0.156	8.096	3.97	4.126
C23	Distribution centers	0.364	8.001	4.183	3.818
C24	Finding the best place	0.002	8.327	4.165	4.162
C25	The best vehicle routing schedule	0.36	8.442	4.401	4.041
C26	Delivery and allocation at the loading dock/dock	0.13	8.263	4.196	4.066
C27	Order preparation and delivery	-0.268	8.479	4.106	4.373
C28	Late and early fees	0.042	8.828	4.435	4.393

The Figure 16 shows the pattern of significant relationships. The given pattern is represented as a chart, where the vertical axis represents the sum of D + R values, and the horizontal axis represents the difference between D and R values. The position and connections of each factor are determined by a point on the chart with coordinates (D + R, D - R) within the device.

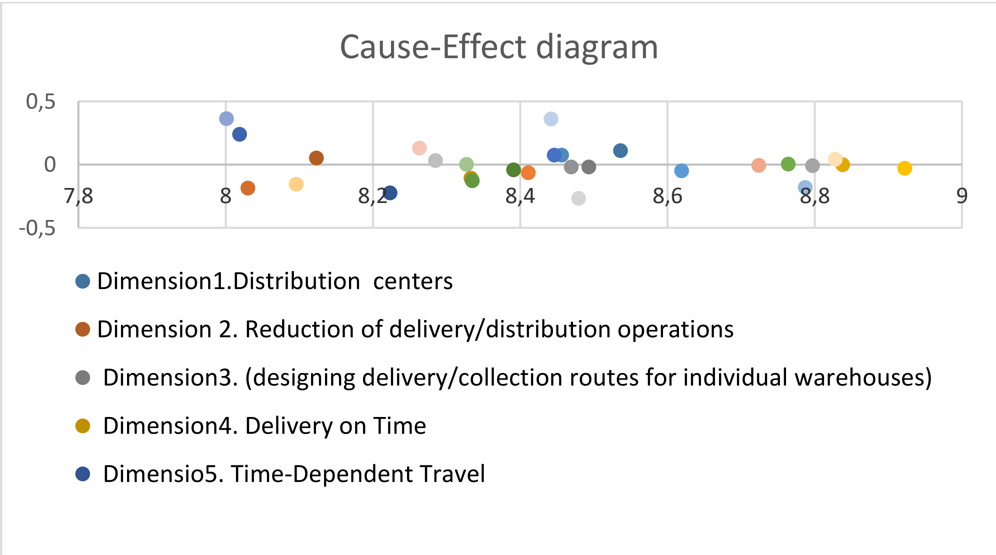

Fig. 16. Pattern of relationships

- *Interpret the results*

Overall, the chart and table provide a comprehensive analysis of the degree of influence and effectiveness of various factors within the system, shedding light on their interrelationships and impacts.

Based on the information provided in the chart and table, the degree of influence of each factor is examined from four different perspectives. The sum of the elements in each row (D) represents the degree of influence of a particular factor on other factors within the system. In this study, it is observed that the distribution centres of criterion 1 have the highest level of influence among all the factors.

Similarly, the sum of the elements in each column (R) indicates the degree of influence of a factor on other factors within the system. According to the research findings, the 19-truck process deviation criterion demonstrates the highest level of effectiveness.

The horizontal vector (D + R) provides insights into the overall influence of a desired factor within the system. A higher value of D + R signifies a greater level of interaction that an agent has with other agents in the system. In this study, it is evident that the reduction of inventory costs, which corresponds to criterion 16, has the most significant impact. On the other hand, the vertical vector (D - R) illustrates the influence of each factor. If the value of D - R is positive, the factor is considered a causal variable, whereas a negative value indicates an effect. In this research, the distribution centres of criterion 1 exhibit the highest level of impact.

- ***COPRAS-G***

The sequential stages of the COPRAS-G method are outlined in the following manner, as documented by (Maity et al., 2012; Bitarafan et al., 2012).

- *When faced with a decision-making problem, it is crucial to carefully choose a set of the most significant criteria that accurately describe the available alternatives.*

- *Create a decision matrix, denoted as* $\otimes X$*, that incorporates criteria values expressed in intervals.*

$$\otimes X=\begin{bmatrix} \otimes x_{11} & \otimes x_{12} & \cdots & \otimes x_{1n} \\ \vdots & & \ddots & \vdots \\ \otimes x_{1n} & \otimes x_{12} & \cdots & \otimes x_{1n} \end{bmatrix}=\begin{bmatrix} [x_{11}, b_{11}] & [x_{12}, b_{12}] & \cdots & [x_{1n}, b_{1n}] \\ & \vdots & \ddots & \vdots \\ [x_{m1}, b_{m1}] & [x_{m2}, b_{m2}] & \cdots & [x_{mn}, b_{mn}] \end{bmatrix} \quad (25)$$

In this context, x_{ij} represents the performance value of the i^{th} alternative in relation to the j^{th} criterion. The value of x_{ij} is determined by considering both the smallest value or lower limit (x_{ij}) and the highest value or upper limit (b_{ij}).

- *we need to normalize the decision matrix* $\otimes X$ *using two equations. Equation (26) is used for* $\boldsymbol{x}_{ij}$ *or lower limit values, while equation (27) is applied for bij or upper limit values.*

$$\bar{\boldsymbol{X}} = [\bar{\boldsymbol{x}}_{ij}] = \frac{2x_{ij}}{[\sum_{j=1}^{n} x_{ij} + \sum_{j=1}^{n} b_{ij}} \quad (26)$$

$$\bar{\boldsymbol{X}} = [\bar{\boldsymbol{b}}_{ij}] = \frac{2b_{ij}}{[\sum_{j=1}^{n} x_{ij} + \sum_{j=1}^{n} b_{ij}} \quad (27)$$

- *Compute the weights or relative importance of the criteria that have been taken into consideration.*

This will help determine the significance of each criterion in the decision-making process.

-
- *The weighted normalized decision matrix* $\otimes X$ *can be determined by applying the provided equations*

These equations play a crucial role in ensuring that the decision matrix is appropriately adjusted based on the assigned weights, allowing for a more accurate evaluation of the alternatives:

evaluation of the alternatives:

$$\otimes \bar{\bar{x}} = [\bar{\bar{x}}_{ij}]_{m\times n} = \bar{\bar{x}}_{ij} \times W_i \quad (28)$$

(i= 1, 2, …., m ; j = 1, 2 , …. , n)

$$\otimes \bar{\bar{x}} = [\bar{\bar{x}}_{ij}]_{m\times n} = \bar{\bar{x}}_{ij} \times W_i \quad (29)$$

(i= 1, 2, …., m ; j = 1, 2 , …. , n)

The weight of the j^{th} criterion is denoted as w_j in this context.

- *Determine the weighted mean normalized sums for both advantageous and disadvantageous factors across all available options through calculation.*

$$\boldsymbol{P}_i = \frac{1}{2}\sum_{j=1}^{k}(\overline{\overline{x_{ij}}} + \overline{\overline{b_{ij}}}) \quad (30)$$

$$\boldsymbol{R}_i = \frac{1}{2}\sum_{j=k+1}^{k}(\overline{\overline{x_{ij}}} + \overline{\overline{b_{ij}}}) \quad (31)$$

- *Determine the minimum value of Ri*

$$\boldsymbol{R_{min}} = \min \boldsymbol{R_i} \; (\text{I} = 1\ 0\ 2, \ldots, \text{m}) \qquad (32)$$

- *The candidate alternatives' priorities are determined by evaluating their Q_i values*

The higher the Q_i value, the greater the priority assigned to the alternative. The relative significance of an alternative indicates the level of satisfaction achieved by that particular option. Among all the feasible candidates, the alternative with the highest relative significance value (Q_{max}) is considered the optimal choice. The (Q_i) is calculated as follows:

$$Q_i = P_i + \frac{R_{min}\ \sum_{i=1}^{m} R_i}{R_i \quad \sum_{i=1}^{m}(R_{min}/R_i \quad)}$$

$$= \boldsymbol{P_i} + \frac{\boldsymbol{R_{min}\ \sum_{i=1}^{m} R_i}}{\boldsymbol{R_i\ \sum_{i=1}^{m}(1/R_i \quad)}} \qquad (33)$$

- *Find the maximum level of importance by evaluating the relative significance value.*

$$Q_{max} = \max Q_i (i = 1, 2, \ldots, m) \qquad (34)$$

- *Compute the Ui value for the i*[th] *alternative using the appropriate formula*.

The relative significance value (Q_i) of an alternative is directly linked to its level of utility. By comparing the priorities of all alternatives with the most efficient one, the degree of utility for each alternative can be determined, resulting in a complete ranking of the candidate alternatives. This degree of utility is expressed as follows:

$$U_i = [\frac{Q_i}{Q_{max}}] \times 100\% \qquad (35)$$

Table 8 displays the initial decision-making matrix X, showcasing the various factors to consider. This table provides the necessary details for the thirteen criteria and five alternatives, presenting the relevant information.

Tab. 8. Initial decision-making matrix

	-1	1	1	1	1	1	1		1	1	1	1	1	1
	0 0 . . 0 0 3 3 5 5 2 2	0 0 . . 2 2 3 3 2 2 9 9	0 0 . . 3 3 0 0 7 7 9 9	0 0 . . . . 2 2 5 5 4 4	0 0 . . 0 0 5 5 0 0 6 6	0 0 . . 1 1 1 1 9 9 3 3	0 0 . . 0 0 4 4 0 0 6 6		0 0 . . 2 2 2 2 3 3 0 0	0 0 . . . . 2 2 4 4 5 5	0 0 . . . . 0 0 4 4 4 4	0 0 . . 0 0 2 2 7 7 8 8	0 0 . . 1 1 1 1 8 8 3 3	0 0 . . 2 2 0 0 6 6 6 6
	C1	C2	C3	C4	C5	C6	C7		C8	C9	C10	C11	C12	C13
A	5 7 0 5	7 8 5 5	7 8 0 0	7 8 5 0	6 8 5 5	8 9 0 0	6 7 5 5		7 7 0 0	8 8 0 5	7 9 5 0	4 7 5 0	7 8 0 9	8 9 4 0
B	5 8 5 0	5 5 2 6	6 7 2 6	7 7 0 5	5 8 7 1	5 5 2 6	4 4 2 6		5 6 2 7	7 8 5 0	6 8 7 6	5 7 0 5	6 8 5 7	7 8 9 8
C	6 7 0 8	7 8 5 5	7 8 0 0	7 8 0 0	7 7 0 8	5 5 5 8	6 7 5 5		6 7 0 0	7 8 5 5	8 7 0 3	5 7 5 3	7 8 6 6	7 8 9 9
D	7 9 0 3	5 6 4 2	5 7 5 2	8 9 0 0	5 9 9 3	5 6 4 2	4 5 4 2		4 6 5 2	8 9 5 5	6 9 9 8	6 8 5 5	6 9 4 7	9 9 0 5
E	8 8 4 9	8 9 0 0	7 8 5 0	7 8 5 5	6 8 3 9	8 9 0 0	7 8 0 0		6 7 5 0	8 9 0 0	7 9 3 4	7 8 9 4	6 9 9 9	8 9 5 6

The range of quantitative utility values for the alternatives spans from 0% to 100%. As a result, the COPRAS-G method enables the assessment of the direct and proportional relationship between the significance and utility degree of the alternatives in decision-making.

The initial decision matrix underwent normalization, and subsequently, the weighted decision matrix⊗X was created and presented in (Table 9). Following this, we proceeded with the previously described procedure to determine the relative significance of each alternative. Table 9 displays the Pi, Ri, Qi, and Ui values for the five cross-docking locations being considered. From the table, it is evident that Scheduling of Vehicle Routing A (5) holds the first rank, followed by Economic Scale (3), Facility Location A (1), Total loading or unloading time (4), and Strategic Decision A (2), respectively, occupying the second, third, fourth, and fifth ranks.

Tab. 9. Weighted normalized matrix

Alternatives	Pi	Ri	1/R	Qi	Ui		Ranking
A	0.0871	0.0147	67.90	0.0965	89.154	89.154	3
B	0.0751	0.0094	106.87	0.0897	82.949	82.949	5
C	0.0866	0.0098	102.14	0.1006	92.968	92.968	2
D	0.0790	0.0100	99.50	0.0927	85.663	85.663	4
E	0.0916	0.0147	67.90	0.1009	93.260	93.260	1

Tab.10. Comparison of Fuzzy DEMATEL and COPPRAS-G

Alternatives	A	B	C	D	E
Name of model	Ranking				
ANP	3	2	4	5	1
COPRAS-G	3	5	2	4	1

The MCDM process has introduced a novel approach called G, which involves expressing attribute values in intervals. This mathematical system is not only logical but also highly effective in handling incomplete information. By utilizing the grey system theory, clear values can be converted into grey numbers, allowing decision-makers to accommodate incomplete information and enhance the accuracy and efficiency of the decision-making process. This integration of G and grey system theory has proven to be crucial in the MCDM process.

Table 10 reveals that the COPRRAS-G method, based on the ANP method, holds significance in determining preference and ranking within Arta Profile Company. This method utilizes grey system theory to convert clear values into grey numbers, thereby aiding in decision-making. As a newly developed MCDM approach, the COPPRAS-G method outperforms the alternative method, as demonstrated in the aforementioned table. Notably, routing scheduling emerges as the primary factor influencing preference and ranking for the company as it pertains to recommending vehicles for the company.

Results

Various manufacturing companies were looking for ways to receive imported raw materials to quickly respond to the production of goods needed by other sectors. Ensuring the accessibility of these imported raw materials to manufacturing facilities is of utmost importance, particularly for companies. Deciding on the transportation and routing of vehicles becomes a crucial aspect of short-term logistics and SCM. Transportation plays a vital role in determining the ultimate cost of imported raw materials during this challenging time while also serving as a fundamental pillar of society and a key sector in any nation's economy. The VRP poses a significant challenge in effectively managing the supply chain of raw materials. Also, locating cross docks for unloading with incoming vehicles and directly unloading them with outgoing vehicles to the right place in compliance with health principles was one of the important issues for production factories, especially for the company. Because the unloading of these raw materials imported by trucks in the appropriate transit port in compliance with health principles to prevent the spread of this disease inside the company was one of the issues that was followed more sensitively by the company. On the other hand, the location of transit docks and their allocation to customers are considered strategic decisions whose optimal time period is 3 to 5 years. In addition, decisions such as scheduling and routing transportation means are related to short-term or operational tactical decisions that require a daily time frame or less than a year. According to the current results of the ANP method, the problem of vehicle routing with a value of 0.34 compared to the rest of the criteria has the highest value, which means that this criterion is of high importance for the company compared to other criteria. Also, the dimensions of performance measurement, location routing, transit load location, and hub location are placed in the next categories with values of 0.24, 0.23, 0.097, and 0.084, respectively. Also, according to the sum of the calculations made through pairwise comparisons and using this technique, strategic decision-making is chosen as the best option. Therefore, locating one or more transit dock systems can be part of the design of distribution networks in a supply chain. So, a strategy is needed to make a decision regarding the position of this cargo. Also, this issue cannot be used separately from the decision regarding how to compensate the goods in the distribution networks. The results obtained from COPRRAS-G show that the scheduling of vehicle routing has the first rank, economic scale, location facilities, total loading and unloading time, and strategic decisions. It is obvious that the company should pay attention to the first option (scheduling vehicle routing). In many cases, the demand of some companies is greater than the capacity of the transportation means. In such cases, it should be possible to provide service to some companies with more than one means. The vehicle routing scheduling problem, when considering the option of demand sharing, expands upon the traditional problem by allowing multiple vehicles to serve companies. This extension offers the potential to decrease costs by both minimizing the total distance travelled and reducing the number of vehicles required. Also, the deviation of the truck process in the transit dock causes the transit docks to face many problems, such as the amount of access to pallets and their displacement, as well as more friction in the belts to connect to the pallets for transportation from trucks to warehouses. Less flexibility of docks regarding truck deviation for loading and difficulty of unloading docks to trucks. On the other hand, regarding the deviation of the truck process, the doors of the exit dock had a problem adjusting the direction of loading from the truck and unloading to the warehouse due to the huge increase in the volume of incoming raw materials. Due to the limited output price for loading and unloading the dock from the truck to the desired warehouses, the distance travelled by the truck to unload the cargo from the dock due to the deviation of the truck's front end, the dock faced the problem of setting the routing schedule, the reason for this is the lack of trucks and equipment. The vehicle was on its way to be loaded from the dock and unloaded to the desired location, with a massive increase in the rate of entry of raw materials and other requirements for the production of the company's product. Therefore, the company should have investigated materials that would not face these problems.

In order to improve the next research and to help the next researcher, the following suggestions are made: similar companies are better for research in order to evaluate the performance of cross docks in relation to the length of the trucks' journey and how to be located in the dock for loading from trucks and unloading. In the desired warehouses, forecasting the necessary travel time between the truck and being placed in the cross-dock should be improved using time series methods. Also, using simulated annealing (SA) or neural networks to better predict the location of transient loads during the Covid-19 pandemic; Use of transit load location using multi-criteria and multi-objective functions to improve and increase work; By examining other requirements for the placement of transit loads, to increase the work output of unloading from the truck and loading to the required spaces in the warehouses, using innovative methods in similar companies.

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