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Optimizing a Distribution Network for Agri-food Products in Algeria Using AnyLogistix Software

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Abstract: Within Cevital, a prominent Algerian agri-food group, increasing demand has resulted in recurrent shortages at several Regional Distribution Centers (RDCs). To address this issue, Cevital has initiated efforts to enhance its distribution network by implementing new storage platforms. This study utilizes Green Fields Analysis (GFA) to optimize the distribution of agri-food products within Cevital, determining the ideal number and strategic locations for these platforms. Using AnyLogistix software, simulations were conducted to model actual product deliveries and generate real-time Key Performance Indicators (KPIs). The primary goal is to support Cevital's decision-makers in establishing an efficient network configuration that reduces transportation costs, meets customer demand promptly, and minimizes CO2 emissions. Scenario analysis indicates that integrating two new storage platforms achieves the best balance in achieving these objectives while maintaining consistent product availability. These findings provide valuable insights for strategically optimizing Cevital's distribution network.

Keywords: Supply chain design, simulation, AnyLogistix®, green fields analysis

1. Introduction

The supply chain represents a complex network of processes that enable companies to transform raw materials into finished products and deliver them to customers. It involves suppliers, manufacturers, distributors, and retailers, interconnected with flows of materials, information, and capital [1].

Supply Chain Management (SCM) is crucial for businesses to efficiently manage production and distribution complexities. It includes the planning, execution, control, and monitoring of all supply chain activities to reduce costs, enhance efficiency, and meet customer needs effectively. Strategic decisions regarding facility size and location, such as factories and distribution centers, are pivotal in SCM, impacting transportation costs, lead times, and responsiveness to demand [2,3]. Optimizing facility locations can benefit every aspect of the supply chain, from suppliers to businesses and customers. Strategic placement improves distribution efficiencies in distance, time, and cost, both between suppliers and facilities, and between facilities and customers [4]. A well-structured distribution network not only reduces transport costs but also improves service quality, making the selection of facility locations a vital factor [5]. Moreover, effective inventory management plays a critical role in shaping distribution networks. Research by Mária Stopková et al. (2024) underscores its importance in maintaining product availability while minimizing costs. By employing suitable optimization criteria, companies can better align their distribution strategies with fluctuating demand, ultimately boosting overall supply chain performance [6].

Within the Algerian agro-food group Cevital, characterized by ongoing evolution new challenges have arisen in managing its distribution network. Facing recurrent shortages in certain Regional Distribution Centers (RDCs) due to increasing demand, the company has embarked on optimizing its distribution network. Thus, the central problem addressed in this study is how Cevital can enhance its distribution network to meet increasing demand while minimizing transportation costs and alleviating shortages in its RDCs.

In the agro-food business, where optimizing distribution networks is crucial, it is essential to consider not only technical factors but also consumer behaviors. A recent study conducted by Dudziak et al. in Poland in 2023 [7] revealed a growing trend towards favoring local products, directly impacting logistical flows. These findings are particularly relevant to our investigation into the optimization of the distribution network for agri-food products in Algeria, where consumer preferences for specific retail outlets or local products could also reshape the network structure. The integration of local supply chains, proximity to retail points, and the rise of online platforms are key factors to consider for effective optimization of distribution network.

Among the widely employed computerized solutions for simulating supply chains and strategies, AnyLogistix stands out. Developed by The AnyLogic Company, this logistics simulation software empowers businesses to intricately analyze, optimize, and model their operations and distribution networks. By integrating modeling, optimization, and simulation, this software provides valuable insights that shed light on strategic logistics decisions [8-11].

This study focuses on optimizing the distribution network for agri-food products within the Cevital Group in Algeria. We use Green Fields Analysis (GFA) through AnyLogistix, it is possible to determine the optimal number and strategic locations for new storage platforms to open. Subsequently, we conduct simulation experiments to model the actual deliveries of products on a GIS map, with detailed real-time generated Key Performance Indicators (KPIs). The objective is to assist Cevital's decision-makers in identifying the most effective network configuration while minimizing transportation costs and ensuring an effective response to customer demand. The originality of this research lies in the innovative application of GFA combined with simulation, providing a practical validation approach to support Cevital's strategic decision-making.

2. Literature Review

The supply chain design problem involves various key decisions, including determining the number and locations of production facilities, capacity allocation , market region assignments, and supplier selections [12]. According to Persson and Olhager (2002), supply chain design defines the structural links between sourcing, production, and distribution activities [13]. Various methodologies, including nonlinear programming, heuristics, graph approaches, and simulation models, have been used to study supply chain design [12].

Currently, most real-world systems are too complex to be fully understood using analytical techniques alone. It is imperative to incorporate a simulation study to address encountered problems. Therefore, when conducting a simulation study, the choice of simulation type becomes a key element [14]. Simulation models are vital in supply chain management, allowing the study of dynamic behaviors over time. Unlike static models, simulations can capture temporal changes, making them useful for understanding decision impacts and disruptions. AnyLogistix, developed by AnyLogic, is a standout software tool for simulating supply chain dynamics, combining simulation and optimization with customizable agent-based functionality [11].

2.1 AnyLogistix® Supply Chain Software

AnyLogistix is a globally recognized software for simulating supply chain and logistics operations. It combines innovative simulation technologies with established analytical optimization methods, making it a versatile tool for analyzing, creating, and optimizing supply chains. This software is notable for its ability to model complex supply chains while providing integral optimization solutions [10,14,11,15].

Several studies have utilized AnyLogistix to support decision-making and achieve meaningful outcomes across various fields. For instance, Plotnikov and Rakhmangulov (2021) used the software to determine the optimal structure of a dry port interaction system in China through discrete event simulation [16]. Ivanov (2019) analyzed disruption risks in production and distribution networks using AnyLogistix, implementing a real-life case study with a disruption scenario in a distribution center [10]. In another study conducted by Ding et al. (2022), AnyLogistix simulated a retail supply chain to examine the effects of disruptions on performance and service levels, highlighting the negative impacts on storage centers [17]. During the COVID-19 pandemic, AnyLogistix proved particularly valuable and was used extensively for research. Ivanov (2020) and Sathyanarayana et al. (2020) used simulation-based approaches to evaluate the pandemic's impact on global supply chains, with a focus on various sectors including retail in Australia [9,16]. Lozano-Diez et al. (2020) applied AnyLogistix to analyze the pharmaceutical supply chain in Mexico, providing insights into its response to disruptions during health crises [19].

2.2 Green Fields Analysis (GFA)

Green Fields Analysis (GFA) is a widely used method in the field of supply chain and logistics management to determine optimal locations for facilities such as distribution centers (DCs), warehouses, and factories. Its objective is to identify the best locations that minimize transportation costs while efficiently meeting customer demand. GFA also helps identify which customers should be served by specific DCs and performs simulations to anticipate changes in demand [20].

Conducting a Green Field Analysis (GFA) required various input data, including customer locations, order volumes, the intended number of facilities, and service ranges. The primary output is the identification of the optimal facility location, often referred to as the "center of gravity." This method streamlines the decision-making process for facility placement, enhancing both efficiency and cost-effectiveness within the supply chain. However, GFA has limitations, as it relies solely on mathematical solution and does not consider real-world factors, such as road networks, geographical features, or available transportation modes [9].

In this method, each customer location is represented by an ordered pair of coordinates (x; y), which are considered fixed inputs or parameters of the problem and remain constant. In contrast, the coordinates (x; y) of the new warehouse, denoted as ($\boldsymbol{P_x}$; $\boldsymbol{P_y}$), are decision variables determined after calculating based on the defined parameters [14]. Transportation costs are assumed to be linearly proportional to both distance and transport volume (demand). Thus, the total transportation costs depend on the coordinates ($\boldsymbol{P_x}$; $\boldsymbol{P_y}$) of potential warehouse locations and the distances involved. The objective function, denoted as Z($\boldsymbol{P_x}$; $\boldsymbol{P_y}$), represents the total sum of transportation costs required to satisfy all customer demands from the warehouse location [14].

$$Z(P_x\,;\,P_y) = \sum_{i=1}^{n} d\big((P_x\,;\,P_y\,);(x_i;y_i)\big) \times \mathrm{D}\,(x_i;y_i), \quad [12] \qquad (1)$$

where: Z (P_x ; P_y) is the objective function, representing the total costs you seek to minimize by choosing the optimal coordinates (P_x ; P_y) for the warehouse; d((P_x ; P_y);(xi;yi)) is the distance between the coordinates of potential warehouse (P_x ; P_y) and the coordinates of customer i (xi;yi); D (xi; yi) is the demand of customer i. The optimal coordinates Px and Py that minimize Z are determined through differential calculus.

This method has seen extensive use in various research and industry applications. For instance, in a study conducted by Kaur et al. (2020) focuses on the distribution of staple foods in tier-A cities in India [21]. Using AnyLogistix software, they performed a Green Field Analysis (GFA) to determine the optimal number of distribution centers for efficient food distribution and to minimize transportation costs. Similarly, Vitorino et al. (2022) examined the distribution network of table grapes produced in the São Francisco Valley region, identifying optimal locations for distribution centers [3]. Additionally, Adhitya et al. (2022) applied GFA using AnyLogistix in a case study on the COVID-19 vaccination scheme for Bali Province, Indonesia. They successfully determined the optimal number and locations of vaccination sites for each regency and the entire province, facilitating more precise and strategic planning to improve vaccination access in remote and sparsely populated areas [20].

3. Data and Methods

The Green Fields Analysis (GFA) in AnyLogistix software version 3.1.0, as applied in this case study, supports Cevital group leaders in determining the ideal number and strategic locations for new storage platforms. Key data for this detailed analysis is sourced directly from the company and supplemented by information from a 2020 publication by Kendi, Radjef, and Hammoudi [22]. This dataset includes customer profiles and geographical locations, product specifications and units of measurement, individual customer demand levels, and transportation costs per kilometer.

3.1 The Company

In Algeria, the agro-food sector has seen significant growth, particularly in food exports, with the private sector playing a key role. Founded in 1998, Cevital is a major contributor to the national economy with diversified operations. In 2012, Cevital created Numilog to enhance distribution efficiency, providing comprehensive storage and nationwide distribution services. Numilog supports various industries with modern logistics solutions [22].

The company follows a distribution plan that involves shipping products from factory to three storage platforms, which then distribute the products to the nearest Regional Logistic Centers (CLRs) for customer pickup. Cevital's current distribution network consists of:

Three production units:

- The Bejaia Plant, which produces and packages sugar, margarine, and various types of oil.
- The Cojek Plant, in El Kseur, Bejaia, manufactures fruit beverages and preserves.
- The LLK Plant, in Tizi-Ouzou, produces and bottles mineral waters and sodas.

Three storage platforms:

- The Bouira Platform, which is: Located in the central region.
- The Constantine Platform, which is: Situated in El Khroub in eastern region.
- The Oran Platform, which is: Located in Hassi-Ameur, western region.

Additionally, there are Eighteen Regional Distribution Centers (RDCs) that complete the setup. Strategically distributed, they ensure efficient product distribution and improved customer service. Seven RDCs are linked with the Oran platform, six with the Bouira platform, and five with the Constantine platform.

3.2 Performing a Green Field Analysis (GFA)

The initial phase of the GFA analysis involves identifying customer locations and operational storage platforms within the distribution network. Customers, designated as Regional Distribution Centers (RDCs), place orders with Numilog RDCs nationwide, which consolidate and forward orders to storage platforms (Oran, Bouira, Constantine).To define customer demand, products like Oil, Sugar, Margarine, Mineral water, and Fruit drinks are added into the Products table. Recurring demand parameters such as order frequency and quantity are specified to accurately model product needs. Demand characteristics, classified as either deterministic or stochastic, are indicated in the 'Demand Type' column of the Demand table, encompassing types like periodic demand and historical demand types. Figure 1 shows the total daily customer demand at the Regional Distribution Centers.

During the GFA experiment, three scenarios are formulated and analyzed based on company objectives and operational constraints:

- Scenario 1: GFA Analysis with the Current Company Network
- Scenario 2: GFA Analysis by Adding a New Storage Platform
- Scenario 3: GFA Analysis by Adding Two New Storage Platforms

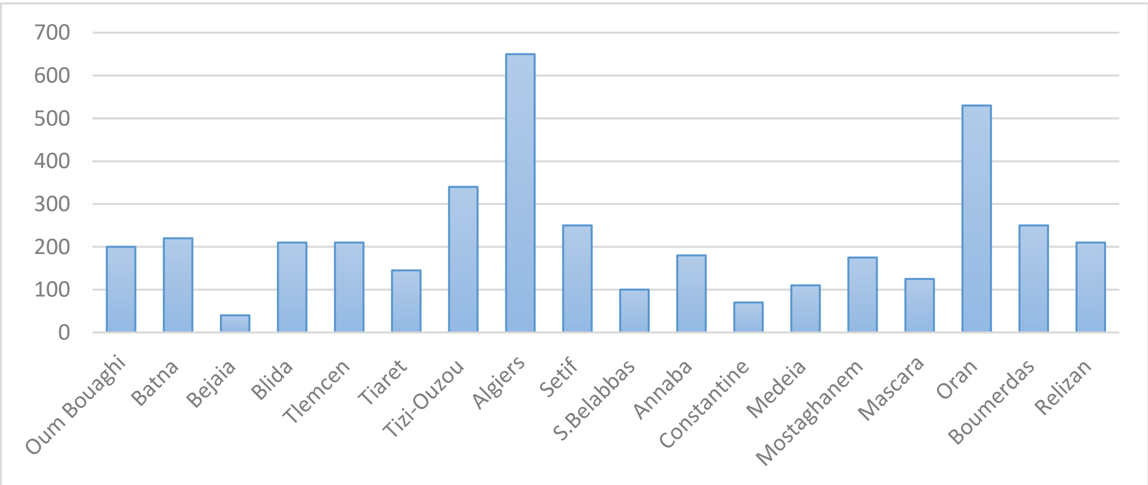

Fig. 1 Total daily customer demand at the Regional Distribution Centers. Source: authors

4. Results of GFA Analysis

The distribution network results for each of the three scenarios are depicted in Figures 2, 3, and 4. Customer locations, referred to as Regional Distribution Centers (RDCs), are shown in blue, while storage platforms are represented in red. The optimal locations for the new platforms are highlighted in green, with their geographical coordinates provided by AnyLogistix:

- GFA DC 1: Latitude 35.945, Longitude 0.892, corresponding to Oued Rhiou in the city of Relizane.
- GFA DC 2: Latitude 36.123, Longitude 5.461, corresponding to Guidjel in the city of Setif.

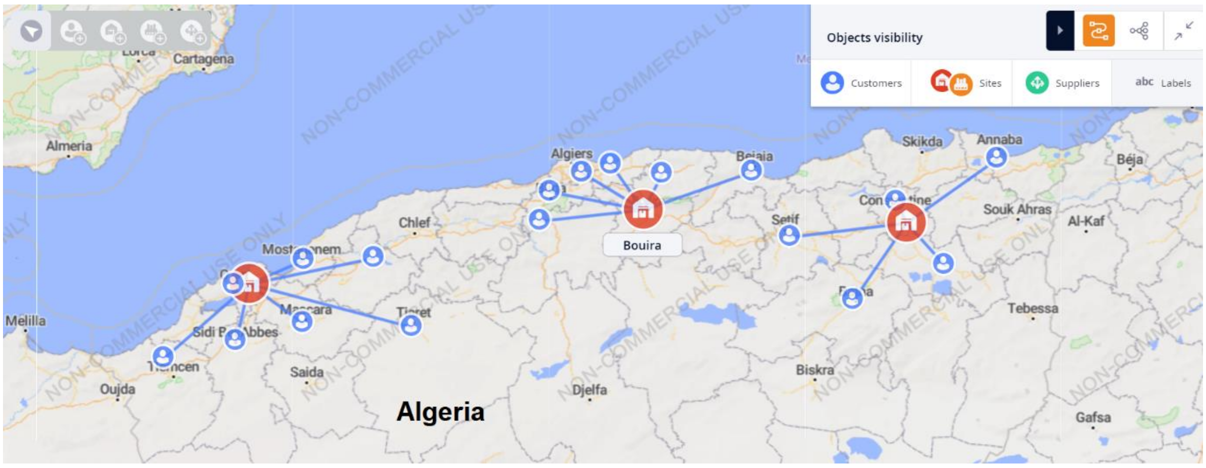

Fig. 2 Distribution Network of Scenario 1. Source: authors

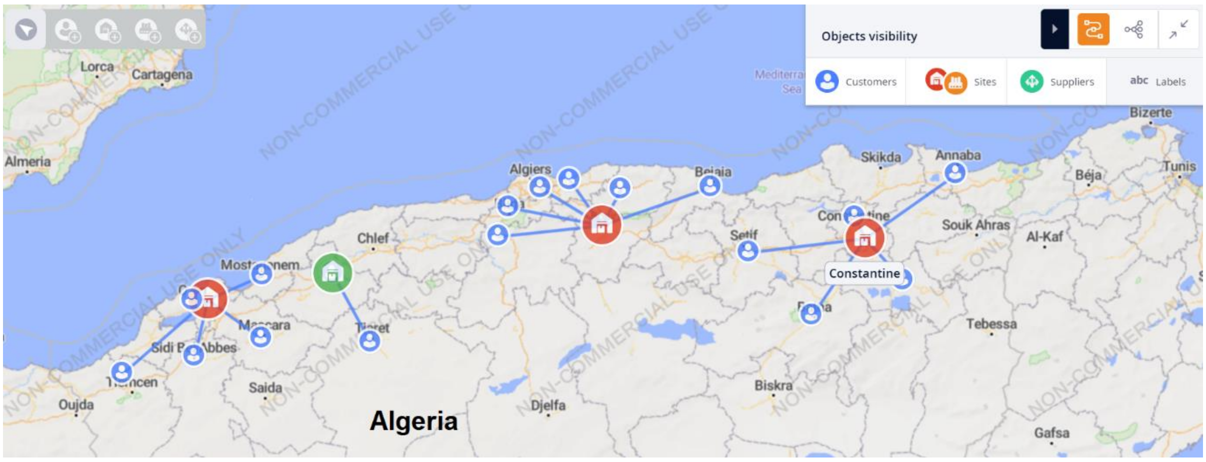

Fig. 3 Distribution Network of Scenario 2. Source: authors

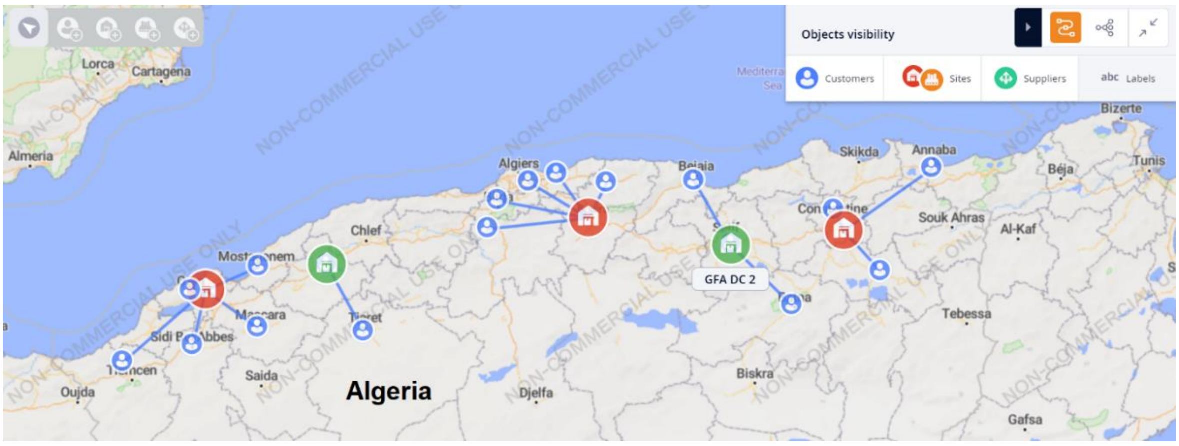

Fig. 4 Distribution Network of Scenario 3. Source: authors

Table 1 provides a comprehensive summary of the Green Field Analysis (GFA) experiment results for each scenario, outlining the flow of goods from storage platforms to Regional Distribution

Centers (RDCs) and the associated distances. Scenario 1, serving as a reference, demonstrates a total distance traveled of 1,475,152 kilometers to meet an annual demand of 1,465,475 pieces. In Scenario 2, the addition of a new storage platform in Oued Rhiou, Relizane, significantly reduces total distances to 1,258.16 kilometers by strategically serving Relizane and Tiaret.

Scenario 3 introduces a second storage platform, GFA DC2, situated in Guidjel, Setif, to cater to the demands of three Regional Distribution Centers (RDCs) Batna, Bejaia, and Setif, has yielded a noteworthy minimum total distance of 1,099.69 kilometers. This outcome signifies an added layer of optimization within the network. Both storage platforms contribute significantly to reducing the overall travel distances.

Table 1 GFA Experiment Results for scenario 1, scenario 2 and scenario 3. Source: authors

Scenario	From Storage Platform	To Customers	Flow (Pieces)	Distance (Km)
Scenario 1	Oran	Mascara, Mostaganem, Oran, Relizane, Sidi Bel Abbes, Tiaret, and Tlemcen	545 675	606.657
	Constantine	Annaba, Batna, Constantine, Oum El Bouaghi, and Setif	335 800	395.191
	Bouira	Algiers, Bejaia, Blida, Boumerdas, Medea, and Tizi-Ouzou	584 000	473.304
	Total		**1 465 475**	**1 475.15**
Scenario 2	Oran	Mascara, Mostaganem, Oran, Sidi Bel Abbes, and Tlemcen	416 100	311.083
	Constantine	Annaba, Batna, Constantine, Oum El Bouaghi, and Setif	335 800	395.191
	Bouira	Algiers, Bejaia, Blida, Boumerdes, Medea, and Tizi-Ouzou	584 000	473.304
	GFA DC1	Relizane and Tiaret	129 575	78.579
	Total		**1 465 475**	**1 258.16**
Scenario 3	Oran	Mascara, Mostaganem, Oran, Sidi Bel Abbes, and Tlemcen	416 100	311.083
	Constantine	Annaba, Constantine, and Oum El Bouaghi	164 250	187.579
	Bouira	Algiers, Blida, Boumerdas, Medea, and Tizi-Ouzou	569 400	359.503
	GFA DC 1	Relizane and Tiaret	129 575	78.579
	GFA DC 2	Batna, Bejaia, and Setif	186 150	162.948
	Total		**1 465 475**	**1 099.69**

5. Simulation Experiments in AnyLogistix

Within the AnyLogistix application, logistics managers and experts can conduct simulations to optimize their processes and perform analyses before actual implementation. This functionality helps in optimizing the capacity of distribution centers, determining their optimal locations, planning, as well as frequently revising inventory control policies and order rules [23]. Based on the results obtained from the Green Field Analysis (GFA), a simulation experiment was performed to optimize our distribution network. Unlike the analytical approach of GFA, this simulation experiment relies on a temporal perspective, allowing us to gather real-time data and generate detailed statistics, including key performance indicators (KPIs) [14]. This simulation approach provides a dynamic operational perspective, enabling stakeholders in the logistics chain to better understand the potential impacts of changes made to the network. It serves as a valuable tool for informed decision-making, continuous optimization, and adaptation to the changing requirements of the logistics chain [14].

- **Transportation Cost**

The annual transport cost for each scenario was estimated using data on unit transport cost per kilometer (89 DZD/km or 0.66 USD/km) and a truck capacity (24 pieces). The calculations ensured that the maximum delivery time remained under one day, utilizing full truckload (FTL) capacity and an average driving speed of 90 km/h.

- **CO2 from Vehicles**

The increase in commercial exchanges and transported goods volume raises environmental concerns, particularly regarding CO2 emissions from trucks. Calculating these emissions is crucial for identifying effective reduction strategies. Factors such as vehicle type, engine specifications, fuel type, and cargo weight are considered in these calculations [24]. According to Article L1431-3 of the Transport Code [25], CO2 calculation methods follow a standardized approach with four levels of precision. The Level 1 method of the ADEME index, for instance, uses an emissions index per ton-kilometer. A diesel road train with a GVWR of 44 tonnes and an ADEME index of 0.0711 kgCO2e/t.km would emit approximately 1.7064 kg of CO2 per kilometer for 24 tonnes of goods. This index provides a basis for estimating the environmental impact of transport operations based on vehicle characteristics, fuel type, and distance traveled.

Simultaneously, several other key performance indicators (KPIs) have been selected to evaluate and compare the operational performance of the three scenarios. These crucial KPIs include:

- Demand Received (Products)
- Actual Annual Distance Traveled
- Maximum Number of Vehicles Used

6. The Simulation Results

Table 2 presents the simulation results for the three scenarios, offering crucial data to inform Cevital's future optimization initiatives. The comparative analysis of Key Performance Indicators (KPIs) demonstrates that Scenario 3 exhibits notable improvements in CO2 emissions, distance traveled, and transportation costs, attributed to the incorporation of a second storage platform.

Table 2 Simulation Results with AnyLogistix. Source: authors

	KPI	Value	Unit
Scenario 1	Demand Received	1 465 475	Pieces
	Max Number of Vehicles Used	177	Vehicle
	CO2 from Vehicles	10 514 234.536	kg of CO2
	Traveled Distance	6 161 647.06	Km
	Transportation Cost	4 066 687.06	USD
Scenario 2	Demand Received	1 465 475	Pieces
	CO2 from Vehicles	9 237 329.111	kg of CO2
	Max Number of Vehicles Used	168	Vehicle
	Traveled Distance	5 413 343.36	Km
	Transportation Cost	3 572 806.62	USD
Scenario 3	Demand Received	1 465 475	Pieces
	CO2 from Vehicles	8 369 188.235	kg of CO2
	Max Number of Vehicles Used	157	Vehicle
	Traveled Distance	4 904 587.57	Km
	Transportation Cost	3 237 027.80	USD

7. Discussion

The analysis of the simulation results indicates that Scenario 3 is the optimal choice for Cevital, balancing CO2 emission reduction, transportation cost minimization, and vehicle utilization efficiency. Scenario 3 achieves these goals with a consistent demand of 1,465,475 pieces, a minimal traveled distance of 4,904,587.57 km, and a transportation cost of 3,237,027.80 USD, using only 157 vehicles. These findings support strategic decisions aimed at enhancing the sustainability and efficiency of Cevital's distribution network. In contrast, the study by Kendi et al. [22] examines the restructuring of Cevital's distribution networks, focusing on the location and relocation of facilities through mixed-integer linear programming. It analyzes four scenarios, demonstrating that the addition of new platforms, such as those in Algiers and Biskra, could incur additional costs for Cevital while simultaneously reducing expenses for customers. Conversely, the present research combines Green Fields Analysis with simulations to provide an accurate evaluation of environmental and operational performance. This enables Cevital to choose a distribution strategy that aligns with its financial goals and meets growing sustainability and customer satisfaction demands. The originality of this study lies in the innovative application of these methods, validated through real-time Key Performance Indicators (KPIs) to support strategic decision-making.

8. Conclusion

Our in-depth analysis of the Cevital group´s distribution network in Algeria, conducted through Green Field Analysis (GFA) and simulations using AnyLogistix software, provides valuable insights for optimizing logistics operations. By examining three distinct scenarios, it was possible to identify opportunities for improvement, thus providing a solid foundation for informed strategic decisions, allowing for the anticipation of potential impacts of proposed changes before their implementation.

The results of the present study clearly indicate that the strategic integration of storage platforms, represented by GFA DC1 and GFA DC2, significantly contributes to operational efficiency while reducing environmental impact. Scenario 3 emerges as the best option, balancing the reduction of CO2 emissions, decreased transport costs, and resource optimization. However, it is crucial to emphasize that the final decision lies with the company and must align with its financial objectives.

The use of simulation modeling, as demonstrated in this study through the AnyLogistix software, proves to be a valuable tool for understanding the complexities of logistic chains. Notably, the present research extends beyond merely proposing specific recommendations for the Cevital Group. It also serves as a valuable reference for other businesses across various industries.

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