A Hybrid Framework for Fleet Management with Quality Concerns: A Case for The Food Industry

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Abstract

- ***Purpose***

The purpose of the study is to propose a framework for fleet management and make suitable distribution solution choices in the food industry.

- ***Design/Methodology/Approach***

This study reviews the literature to examine food distribution criteria. These criteria are used in the AHP assessment and combined with discrete events simulation in a structured framework, which is validated through an empirical study.

- ***Findings***

The empirical case results demonstrate that both the analytic hierarchy process (AHP) and discrete events simulation converge toward the same solution in most cases.

- ***Originality***

This study contributes to the literature on distribution management and develops a framework that can both guide future research and aid logistics practitioners in analysing distribution decision-making systems in dynamic environments.

Keywords: framework, distribution, logistics, fleet management, food industry

1. Introduction

Transportation is one of the most fuel-intensive sectors (Acar *et al.*, 2020). Given the different optimisation challenges in the supply chain (Fares and Lebbar 2019), managing the goods' transportation to the customer in the right condition is key to operational performance success. The distribution complexity increases for basic goods with massive frequency and volume, such as in the food industry.

The problem for a food industry producer is selecting the best fleet distribution solution, which is worth analysing as a product's perishability and demand variability patterns are unique features of the food supply chain (Novitasari *et al.*, 2018). Consequently, they impact the performance measures and the food supply chain (Sufiyan *et al.*, 2019).

The main gap observed in the literature is the limited focus on the multi-criteria decision-making systems for the best fleet distribution solution in the food industry. Buyukselcuk (2019) attempted to determine the right logistics firm using multi-criteria decision-making (MCDM), but the scope was limited to cold chain logistics. Similarly, El Raoui *et al.* (2018) and Martins-Turner *et al.* (2020) focused on the routing vehicle problem in the food industry. Therefore, our motivation is triggered by the issues encountered in routing management within transit service, including scheduling and speed regulation (Rojas *et al.*, 2020).

To fill this gap, the main research question (RQ) that we aim to address in this study is:

RQ: *What is the current optimal solution for the fleet management of final product distribution from the producers to first-tier customers in the food industry?*

In this context, we employ both the discrete event simulation and fuzzy multi-criteria decision-making methods. We build on the current literature by combining discrete-event simulation tools and the AHP technique (Garrido *et al.*, 2021). As our study involves a set of conflicting criteria with a finite set of possible alternatives, MCDM methods can be employed to effectively address such a problem (Senthil *et al.*, 2018). To validate our study, we conduct an empirical study on a carbonated soft drink company. Even if these final products are not perishable, they have seasonality, and the demand for beverages depends on the weather (Sánchez-Romero *et al.*, 2020).

The contributions of this study are as follows:

- We present a hybrid AHP-simulation framework for improving the distribution of the final goods, and the analysis is implemented through a literature-simulation package.
- We conduct a case study to demonstrate the application of the method in the real world.
- We demonstrate the impact of various criteria associated with quality, delay, and cost on the selection of the best distribution solution in food distribution through a sensitivity analysis.

The remainder of the paper is structured as follows. A literature review and a theoretical background are outlined in section 2. The method used and the framework design are explained in section 3. The empirical case is outlined in section 4. Section 5 presents and discusses the results. Finally, we conclude the study along with theoretical and practical implications and future research recommendations in sections 6 and 7, respectively.

2. Theoretical background and literature review

The literature review for this study is articulated into three streams. A theoretical background on food distribution is outlined in Section 2.1, and Section 2.2 describes the relevant methods for fleet and distribution management in the food industry. We conclude by highlighting the research gap in Section 2.3.

2.1 Theoretical background

Food supply chain management is defined by Haleem and Sufiyan (2021) as "the management of supply and demand by using resources effectively and efficiently across the food supply chain, through strategic coordination and collaboration of stakeholders, to create value for improving its performance, while providing safe and quality food to consumers in a sustainable and timely manner". The main issue in the food supply chain is obtaining resources from suppliers and ensuring the food movement from producers to buyers (Barman *et al.*, 2021). Thus, food supply chain transportation is associated with fuel consumption and traffic congestion (Jouzdani and Govindan, 2020). Additionally, food supply chain items are differentiated from other supply chains because of various unique features, such as the considerable and constant variations in food product quality from the upper-hand side to the lower-hand side of the chain (Jouzdani and Govindan, 2020). For instance, in agricultural operations, agri-fleet management is challenged by numerous issues, such as fuel price volatility and fleet cost reduction (Achillas *et al.*, 2019). Consequently, food distribution differs from that of other products. Quality, health, and safety are pivotal requirements in food distribution (Akkerman *et al.*, 2010). Distribution management in the food industry is challenging due to the time window for product delivery and the limited shelf lives of food products (Akkerman *et al.*, 2010).

2.2 Methods for fleet and distribution management in the food industry

2.2.1 Simulation

Simulation has been increasingly used in supply chain analysis as the cost and demand variability, and associated supply chain issues can be handled with such techniques (Sun *et al.*, 2021). By examining real-world problems, simulation models can assess different scenarios of the food supply chain. Govindan and Al-Ansari (2019) investigated delivery fleet optimisation in CO2 fertilisation networks to enhance food production systems while using simulation-based reinforcement learning. They emphasise training the CO2 distribution agent to optimise delivery fulfilment and network utilisation rates. Their findings have significant implications for planning the expansion of greenhouse networks, specifically in Qatar. Nevertheless, they considered only a single agent, and the simulator incorporated agent functions.

El Raoui *et al.* (2018) explored an Agent-Based Model integrated with Geographic Information Systems simulation for urban freight distribution of perishable food. Their simulation model determines the quickest routes to transport fresh products. Their study highlighted the development of a time-dependent scheduling technique for costs and CO2 emission savings. Even if this scheduling enables the optimisation of departure times from the distribution centre, this time-dependent vehicle routing problem was not represented as an optimisation model. Martins-Turner *et al.* (2020) analysed the electrification of urban freight transport by focusing on a case study of the food retailing industry. They handled the vehicle routing problem using agent-based transport simulations to model distribution to food retail shops. Their findings showed that even without significant changes in the carriers' operating policies, considerable electrification of freight delivery tours could be performed with current technology. Nevertheless, this study did not provide holistic insights into decision-making systems for freight transportation.

2.2.2 Multi-criteria decision-making systems

MCDM techniques have been widely used for supply chain analysis. Recent applications include prioritising risk elements for the Halal food supply chain (Khan *et al.*, 2019). Sufiyan *et al.* (2019) explored food supply chain performance using hybrid fuzzy MCDM techniques. They suggested an integrated food supply chain performance measurement framework. They ranked and examined the interdependence relationship between the performance criteria and indicators of the food supply chain. Nonetheless, they provided limited contributions to distribution policies.

Buyukselcuk (2019) handled the food transportation issue, specifically for cold chain, and determined the best cold chain transporter for a small and medium sized company operating in the food industry. They used MCDM to choose the best logistics firm for the firm under study and evaluated the alternatives and vehicle fleet criteria. Similarly, Segura *et al.* (2019) analysed measuring products and suppliers' sustainability for food distribution companies. They used the MCDM approach to get the indicators to evaluate food quality and assess them from a sustainability perspective. The study enabled the classification of suppliers using social criteria. However, neither Buyukselcuk (2019) nor Segura *et al.* (2019) included vehicle amortisation criteria; while studying the fleet size and mix vehicle routing problem, it has been argued that if the distributor owns the fleet, fleet amortisation is among the largest vehicle costs (Desrochers and Verhoog, 1991).

2.3 Research gap

Table I synthesises a comparative analysis of recent research associated with simulation and MCDM for a food industry supply chain analysis. Despite the significant efforts made in the food supply chain, the following gaps remain unaddressed:

[Insert Table I here]

1. The interactions among criteria associated with food industry literature influencing food distribution choices have not been thoroughly investigated. Although Buyukselcuk (2019) highlighted the hierarchy of criteria associated with logistics firm selection, their scope was limited to the cold chain and not generalised to the food supply chain.

2. Few studies have investigated the strengths of both simulation and AHP in food distribution. While it has been argued that using MCDM methods and a simulation tool can present a comprehensive model for selecting a suitable alternative (Kannan *et al.*, 2020), recent applications of a hybrid MCDM framework and simulation include the assessment analysis of the worst polluted cities (Raheja *et al.*, 2022)

Thus, to address these gaps, a hybrid approach—combining both the MCDM, namely the AHP technique and discrete event simulation—is developed to make the optimal fleet management decision in the food industry. A hierarchical investigation of the interactions among the key influencing factors in food industry distribution is undertaken, along with various scenario analyses.

3. Method and framework design

We first explain why we used simulation and AHP for this study. Subsequently, we describe each of them, along with the steps of the designed food distribution management framework.

3.1 Integrating simulation and AHP

The main advantage of simulation is that it provides several benefits over mathematical and experimental modelling due to its marginal cost, flexibility, accuracy, and realism. Hence, several researchers consider it a powerful approach (Bajjou and Chafi, 2021). However, as a simulation is based only on cost analysis, a disadvantage of using it in isolation is a weak holistic consideration of the other criteria that could impact the distribution solution. To overcome this constraint, we integrated simulation with MCDM. Precisely, AHP enables applying both qualitative and quantitative criteria while assuring quality using consistency indices (Kumar *et al.*, 2021).

3.2 Discrete event simulation

Computer simulation is efficient as it provides an appropriate environment where decision-makers can design, analyse, and improve processes using a controllable and low-cost system. (Bajjou and Chafi, 2021). The discrete event simulation model approach is a total system approach that enables analysis of the dynamic and stochastic behaviours of a process and all its subcomponents (El-Khalil, 2015). The ability to mimic the dynamics of the real system provides discrete event simulation with structure, function, and a unique way to analyse results (Moon and Phatak, 2005). Several researchers have presented process flows by outlining the steps followed in a simulation study. It has been argued that all the frameworks are not rigidly sequential and that the first step of problem formulation is as much an art as a science (Eldabi *et al.*, 2002).

3. AHP

AHP is a multi-criteria decision-making system that breaks down the decision problem into a hierarchy of interconnected elements (Zahedi, 1986). It has been widely used and integrated with other managerial tools. Recent applications include post-pandemic maturity management (Fares and Lloret, 2022) and the classification of total quality management practices for implementation in steel industries (Bajaj *et al.*, 2019).

After performing the pair-wise comparison between criteria, sub-criteria, and alternatives, the consistency index (CI) is calculated as follows:

$$\text{CI} = \frac{\lambda_{max} - n}{n - 1} \quad (1)$$

Knowing that λ_{max} indicates the maximum value of the pair-wise matrix and *n* is the number of criteria, the consistency ratio (CR) is calculated as:

$$\text{CR} = \frac{CI}{RI} \quad (2)$$

While RI is the random index defined in Table II.

[Insert Table II here]

3.4 Framework design

To answer the main research question of this study, and based on the two methods mentioned above, we developed a framework (Figure 1) structured on the four steps as follows:

[Insert Figure 1 here]

- Step 1: Definition of the scope of the distribution problem. This includes problem features such as distribution points, shipping destinations, and regional scope. In addition, food manufacturer stakeholders are required to define the list of potential solutions for the distribution problem, that is, the alternatives.
- Step 2: Based on the current literature (Eldabi *et al.*, 2002), we summarised the simulation steps followed in this study as:
  - Model conceptualisation and data collection
  - Model formulation and translation
  - Experimentation and validation
  - Results and output data analysis

Verification should continue throughout the study and construction of the computer model:

- Step 3: A breakdown structure of the criteria of the distribution management of final products in the food industry is analysed based on the literature. Table III presents a total of three criteria and nine sub-criteria.

[Insert Table III here]

- Step 4: We compared and validated simulation results with an AHP ranking. The multi-criteria sensitivity analysis results were also presented, and the implications for managers were provided.

4. Empirical case study

An empirical case study was conducted in collaboration with a subsidiary of a soft drink manufacturing firm operating in the food industry in Tangier, Morocco. The main purpose was to optimise the internal transport flows of the company in an offshore country for local distribution points. To route its products to its customers from two production points and to 13 customers located between zones A and B, the company needs to select the best alternative from the following:

- Amortised: It uses its own means of transport. Some of them are depreciated depending on their operating frequency and their technical characteristics.
- Non-amortised: This alternative consists of purchasing new transportation vehicles by the soft drinks firm.
- Outsourcing: It entrusts the transportation of its products to a second party, which uses its own means of transport under a contractual agreement.

The study analysed the internal flows according to the customers' demand and the characteristics of each scenario to help the company make adequate choices compared to the current routing system of its products.

4.1 Data collection

The simulation data was collected from the logistics and supply chain departments. The input data for the simulation is twofold. First, the forecast for the weekly shipment was provided (Table IV). Second, the total cost of each shipment from the producer to the distribution cities was provided. For the first and second alternatives (i.e., amortised and non-amortised options), the costs were based on the fixed and variable costs plus the amortisation costs of each shipment. The total costs are outlined in Table V.

[Insert Tables IV and V here]

For AHP, the weighting of the delay and quality criteria was done by an expert who has previously worked for that company, while an automotive industry expert did cost weighting. Both experts had more than ten years of experience. Experts were asked to provide judgment based on the paired comparison (Afzal *et al.*, 2020). For the weighting scale, we assumed no equality in judgment. Hence, compared to Satty's scale for AHP, we considered 1 as weak instead of equal. The scale adopted in our study is outlined in Table VI.

[Insert Table VI here]

4.2 Data analysis

For simulation, we modelled our case with Arena software. Rockwell ARENA is simulation and automation software from Rockwell Automation Inc. (Neeraj *et al.*, 2018). The recent use of Arena in the literature for discrete event simulation includes additive manufacturing (Kamali *et al.*, 2022) and patient flow in clinical practices (Maass *et al.*, 2022).

We modelled the demand of 15 customers spread over the two zones. The modelling for each city is outlined in Figure 2. For each input data of city demand, we analysed the statistical patterns such as the distribution and the chi-square test (Table VII). For each customer, the requested delivery was modelled with the Create block; this module was designed as a starting point for entities in a simulation model. Entities were created using a grid or based on the time between arrivals. The entity type was specified in this module.

Regarding the transfer of products, we modelled it with the Transfer block, the duration of which is determined with the variable "Duration City x". Then, the price was assigned via the Assign block, which allowed us to assign a value to an attribute or a variable. It is the equivalent of a local variable in computing. Finally, the entity was placed in the Dispose block, which bore the name of the city; this module was designed as the endpoint for the entities in a simulation model: the destruction of the entities. For demand forecasts, we studied the mathematical distribution law of each variable using the input Analyzer module. Finally, the Process Analyzer module compared the different alternatives.

[Insert Figure 2 here]

[Insert Table VII here]

For the AHP analysis, we used the Expert Choice software. The advantage of using this software is that it enables decision-makers to make the best decision with a clear picture of the decision and visual integration in testing the sensitivity analysis (Yunus *et al.*, 2013). It has been recently used by Erdogan *et al.* (2017) for decision-making in construction management.

When analysing the hierarchy of AHP, our multi-criteria structure analysis consisted of four levels. The first level presents the decision goal, and the second level outlines the criteria followed by the sub-criteria illustrated in the third level. Finally, the fourth and final level presents the three alternatives for the transportation solution.

As a result of the comparison of the main criteria (Table VIII), cost has the most significant weight with 0.729. Subsequently, we assessed the sub-criteria impact. ‘Fixed costs’ have the highest weight of 0.667 among the first criterion group (Table IX). ‘SKU transit lead time’ has the highest weight of 0.688 among the second criterion group (Table X). Finally, ‘Responsiveness quality’ has the highest weight of 0.673, among the third criterion group (Table XI).

[Insert Tables VIII to XI here]

Concerning the last hierarchical level, alternative solutions have varied among the sub-criteria. Tables XII, XIII, and XIV outline the results for the three groups of criteria: cost, quality, and delay. Figure 5 shows the normalised value of the decision based on criteria weights (Figure 6). We found that outsourcing and keeping amortised vehicles are both solutions with the highest priority, with 0.393 and 0.339 weights, respectively. However, purchasing new vehicles is the least feasible option, with the lowest weight of 0.267.

[Insert Tables XII to XIV here]

5. Results and discussion

5.1 Simulation results

The simulation results are illustrated in Figure 3. The Process Analyzer module compares the different alternatives while considering only the cost criteria and building on the forecast demand simulation. The conclusion is that the most cost-effective solution based on the simulation of fixed and variable costs is to keep using the amortised vehicles.

[Insert Figure 3 here]

Similar to the literature, taking the amortisation factor into account in our study supports Sawik *et al.* (2017), indicating that vehicle amortisation, along with driving time, drivers’ salaries, and fuel consumption, are among the main costs associated with goods delivery. Similarly, Csehi and Farkas (2016) argued that there is an amortisation cost depending on the sinuosity, quality, and length of the road when they analysed the truck routing and scheduling problem to find the best route between the starting and ending location. Another aspect of transportation management applied to waste management has been investigated by Kolukisaoğlu *et al.* (2018). They discussed that the main associated operational costs are linked to the collection and transportation of waste, including truck amortisation, fuel costs, and personnel costs.

5.2 AHP results and sensitivity analysis

AHP results indicate that when considering other criteria for the analysis of the decision system besides cost, results are slightly different from simulation output. Figure 4 illustrates the normalised values of the decision, as per the criteria weights (Figure 5). It has been found that outsourcing and keeping amortised vehicles are both solutions with the highest priority, with 0.393 and 0.339 as weights, respectively, with a very weak gap. While purchasing new vehicles is the last option, with the lowest weight of 0.267.

[Insert Figures 4 and 5 here]

A sensitivity analysis was performed on the AHP analysis to assess the results' robustness. We changed the input weights and evaluated the results. The number of possible combinations of the three criteria ranking is expressed as:

$$3! = 1 \times 2 \times 3 = 6 \tag{3}$$

Based on the experts' input, the initial results outlined the following ranking: Cost>delay>quality. This means that five cases remain for the sensitivity analysis. Figures 6–15 illustrate the sensitivity analysis results. We define the five cases as follows:

- Case 1: cost> quality > delay
- Case 2: quality >cost>delay
- Case 3: quality > delay > cost
- Case 4: delay>quality>cost
- Case 5: delay> cost > quality

[Insert Figures 6 to 15 here]

In accordance with the literature, considering quality concerns in our study supports Van der Spiegel *et al.* (2005). Hence, stating that the food sector requires an especially high level of quality assurance, knowing the specific production features such as restricted shelf life. Similarly, Liu and Wang (2020) argued the importance of logistics outsourcing in the fresh products industry for the quality assurance of fresh products. They found that fresh food firms increasingly focus on resources for promoting their core business while outsourcing their cold chain. In a broader context, regardless of the industry, firms might outsource logistics functions either completely or partially to maximise organisational benefits (Zailani *et al.*, 2015). Therefore, firms' stakeholders should determine the range of logistical activities to be outsourced and those to be conducted internally, which leads to several logistics service provider types. Todorovic *et al.* (2018) defined a logistics service provider or third-party logistics (3PL) provider as a specific outsourcing activity associated with distribution and logistics. The 3PL manages collecting outbound shipments from shippers, consolidating goods in a distribution centre, and distributing them to the receivers. However, the level of outsourcing might differ among the four levels: warehousing and transport (level 1), value-added activities (level 2), planning and control (level 3), and total outsourcing or distribution network management (level 4). Nonetheless, despite the extensively known importance of logistics outsourcing, Zhu *et al.* (2017) stated that the literature has acknowledged that logistics outsourcing does not necessarily ensure satisfying results. This is due to the uncontrollable behaviour of the 3PL providers if they fail to handle the different types of outsourcing activities.

5.3 Scenarios analysis

The scenario analysis summarised the results of this empirical case study. One scenario was presented from a mono-criterion analysis (simulation), while six scenarios were presented from a multi-criteria analysis (AHP).

- If cost analysis is the only criterion to consider, discrete event simulation findings demonstrate that amortised vehicles are the best alternative.
- If additional food industry criteria are considered besides costs, AHP findings show that outsourcing is the best alternative based on the initial criteria weighting, with a very weak gap, compared to the amortised vehicle alternative ranked second. However, if there is a variation in

the criteria weighting, the AHP sensitivity analysis shows that if cost> quality > delay, quality >cost>delay, quality > delay > cost, delay>quality>cost, and delay>cost > quality, then also an amortised vehicle is the best alternative.

Additionally, our findings about the delay criterion support the findings of Yaacob *et al.* (2018). They state that delay is one of the risk categories in Halal food transportation, which is mainly due to several factors such as traffic congestion, containerisation troubleshooting, and other government agency issues. Our results on time delay impact also support the statements of Kalantari and Hosseininezhad (2022). By investigating a sustainable global food supply chain with risk considerations, the author included time delay risk in their model, as the deterioration risk in perishable food necessitates proper transportation; otherwise, inventory might deteriorate before being used. Regarding the quality criterion, our study supports Sadiku *et al.* (2019). They stated that product quality, along with health and sanitation concerns, are significant issues in the food industry. Hence, food community needs should be satisfied with regard to distribution, availability, and quality of food. Finally, with reference to the cost criterion, Li *et al.* (2020) discussed the costs associated with fresh food logistics. Specifically, there is an exigency to control the temperature of the freezing chamber. Therefore, the electricity consumption for refrigeration results in higher costs for the vehicles in fresh food logistics.

6. Implications

6.1 Practical implications

In association with the research questions, we provide a hybrid framework that helps professionals dynamically choose the current optimal solution for fleet management of final product distribution from the producers to first-tier customers in the food industry. The framework integrates mono criterion via simulation and multi-criteria analysis via AHP. With reference to our empirical findings, the simulation results based on modelling only cost criterion demonstrate that using amortised vehicles is the best alternative. While including the multi-criteria hierarchical analysis with two additional criteria besides cost as their sub-criteria, the results show that outsourcing is the best alternative, being slightly preferred to the amortised vehicle alternative, which is ranked second. However, the criteria weighting might change because the human assessment makes the ratings subjective and the eventual organisational changes of business demand. Therefore, AHP sensitivity analysis results reported that for the five remaining possible combinations of criteria ranking, the amortised vehicle alternatives are always the same. Hence, both methods generally yield the same results. From this point of view, AHP multi-criteria decision-making can be considered an analysis tool to verify the discrete event simulation results. These results do not apply to other cases as they were not tested in other instances. However, similar studies can be carried out for problems by taking the managerial inputs of the firm's alternative solutions and the expert weighting.

On a broader scope, food industry firms' practitioners can also benefit from our study. The suggested framework can be used by decision-makers (i.e., logistics and supply chain engineers/managers) to confirm which distribution fleet modality is suitable for their needs and objectives among the set of alternatives. While our study included general food distribution criteria, specific food firms can adapt the criteria based on their needs. Particularly, fresh food, cold chain, and highly perishable agricultural products are highly sensitive to quality criteria. It may lead to a deeper hierarchy of the associated criteria that may be beneficial for each business case. In this way, this study can also provide directions to improve the fleet transportation function in the supply chain.

6.2 Theoretical implications

Theoretically, this study extends fleet management decisions in the food industry. The suggested framework contributes to the fleet management efforts (Xidias *et al*., 2022 and Brlek *et al*., 2022) to manage the transportation system and enhances the food supply chain management efforts (Kabadurmus *et al*., 2022), given its unique features. It presents a comparison between mono-criterion and multi-criteria analysis. The presented sensitivity analysis is not limited to managing the inputs of basic multi-criteria decision systems but is supplemented with a scenario analysis based on the number of criteria to be considered. Furthermore, by examining how AHP and simulation methods can advance fleet management by deciding on the best distribution solution in the food industry, we build on the theory of combined AHP and simulation (Garrido *et al.*, 2021).

7. Conclusion and future research scope

Several distribution strategies have been developed to meet changing consumer preferences. In this context, the food industry is among the most challenging industrial markets. For instance, designing fresh food distribution networks is complex because of the constraints and variables, including product deterioration and the associated transportation difficulties (Yadav *et al.*, 2021). Fleet management is a highly efficient way to handle the costs, delays, and quality of distribution networks. However, selecting the best option for business is a complex problem. This complexity is attributable to various influencing factors, such as uncertainty and the changing demand and scheduling input behaviours of the distribution system. Thus, it is important to support fleet management for the distribution network in a timely and reliable way. A hybrid discrete event simulation–AHP method has been used in this study. For this purpose, a simulation model of distribution services for food products has been constructed while considering demand forecasts. Arena is compatible with entity flow control and simulation-oriented modelling (Wang *et al*., 2009). The simulation results are later validated by AHP, where a breakdown structure of multiple criteria for food distribution factors has been designed on a hierarchical arborescence. An empirical study has been conducted with a carbonated soft drink company. The study has assessed real-life inputs from experts while selecting one of the three alternatives presented by the firm's stakeholders.

The contribution of this study is two-fold. First, we add to the multi-criteria analysis influencing the selection of fleet distribution solutions in the food industry. An inclusive set of evaluation criteria is extracted from the literature review for the decision-makers in this area. At this stage, our work is a continuation of Buyukselcuk's (2019) study that determined the right cold chain logistics firm with a hieratical criteria analysis. We granulate the analysis in this section to the broader food industry context. Second, the study contributes to the organisational decision-making system for dynamic food distribution systems.

On the one hand, most MCDM methods can provide inaccurate decisions due to the ambiguity and multiplicity of meaning when decision-makers perform evaluations (Ayağ, 2007). However, they have the advantage of a more holistic view compared to the criteria-based methods as they enable the problem perceptions with respect to various criteria. On the other hand, despite the criteria analysis of our discrete simulation model based on cost analysis, simulation enables the dynamic modelling of real discrete instances. In other words, the proposed framework provides a valuable tool for a decision-maker to make the best fleet distribution decision. Hence, our hybrid approach addresses the limitations of both methods by complementing the results of each one of them. Therefore, we enrich the literature on the applications of research using both AHP and simulation.

The applicability of the results on other cases or data instances has not been tested. For instance, the applicability of this framework can be investigated in other industrial sectors where a high volume of goods is encountered, such as fast fashion (Fares and Lebbar, 2019). It could be achieved by replacing the hierarchy criteria analysis with other key factors associated with the specific features of the distribution industry network under study.

Future research can apply the fuzzy approach to validate the findings and even compare the results with other MCDM methods, such as Fuzzy VIKOR (Rathore *et al.*, 2021), which could be implemented within the suggested framework. Moreover, considering the current pandemic (Fares and Lloret 2023, Fares *et al*., 2022), several studies have emerged on food distribution concerns (Singh *et al.*, 2021) and food supply chain resilience (Hobbs, 2021). Furthermore, including deep neural networks (Ke *et al.*, 2022) and reinforcement learning (Zheng *et al.*, 2022) could have great potential for modelling fleet distribution in food industry networks.

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Figures

Figure 1: The suggested framework

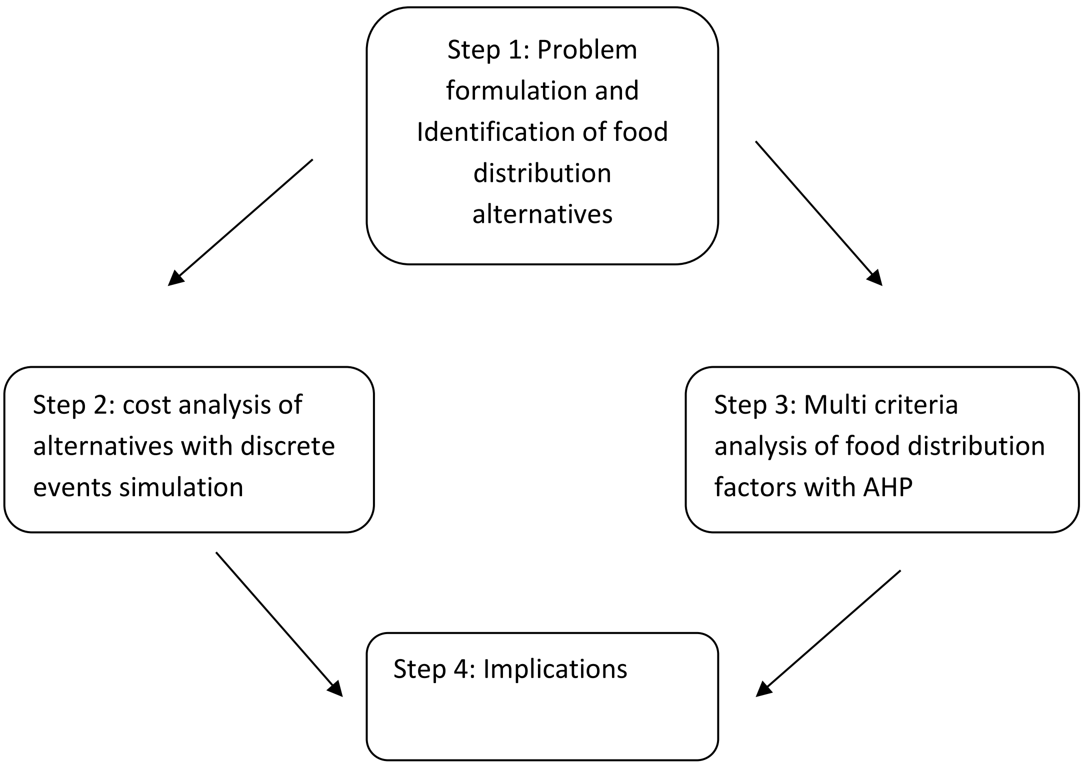


Figure 2: Example of the simulation model for city x

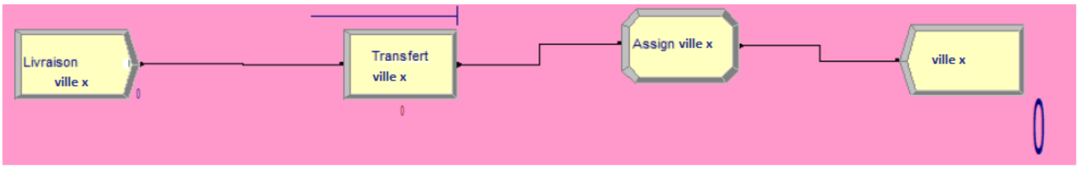


Figure 3: Simulation results

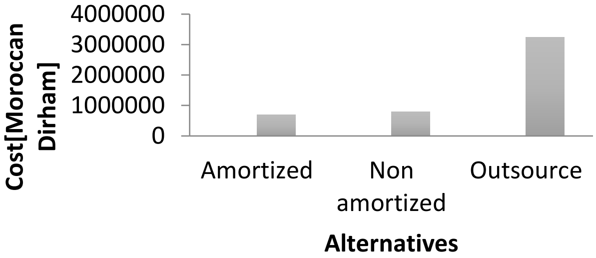


Figure4: Multi-criteria analysis results

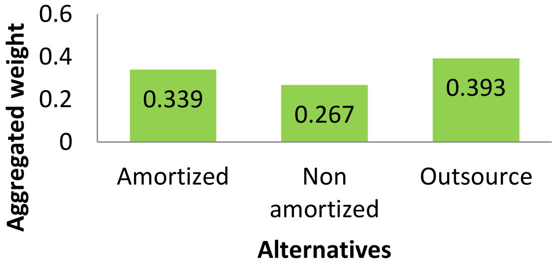


Figure5: Aggregate weights results

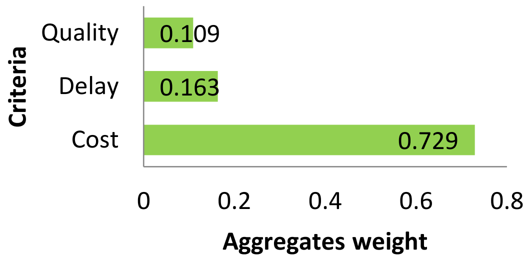


Figure 6: Case 1 sensitivity analysis results

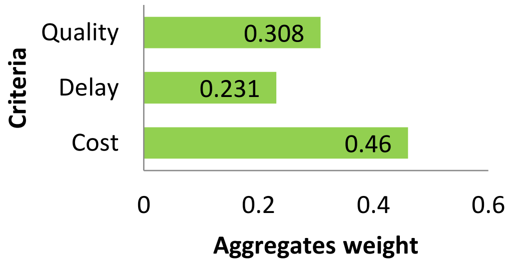


Figure 7: Case 1 aggregate weights sensitivity variation

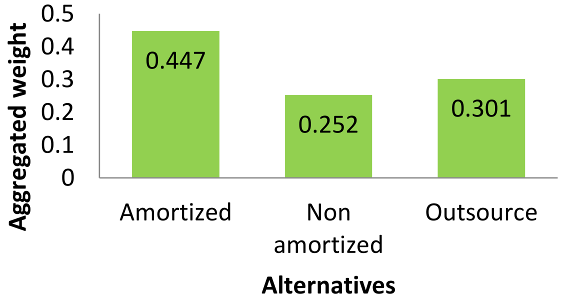


Figure 8: Case 2 sensitivity analysis results

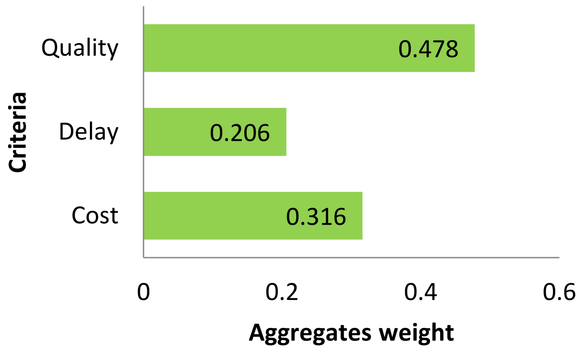


Figure 9: Case 2 aggregate weights sensitivity variation

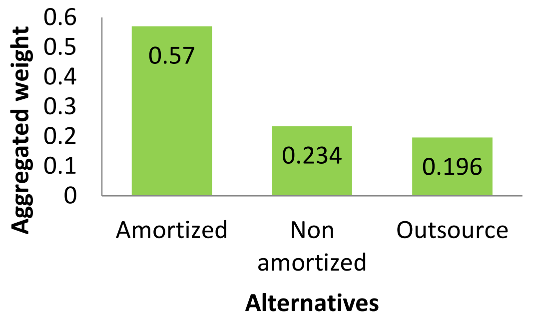


Figure 10: Case 3 sensitivity analysis results variation

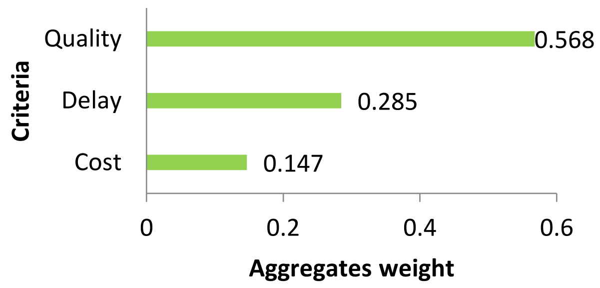


Figure 11: Case 3 aggregate weights sensitivity variation

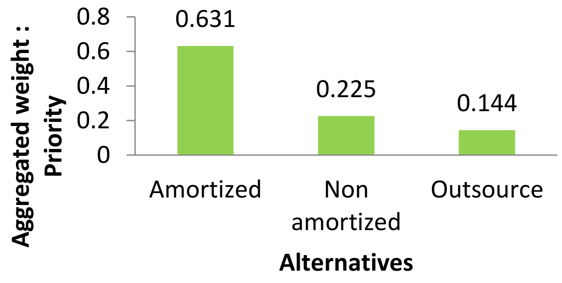


Figure 12: Case 4 sensitivity analysis results

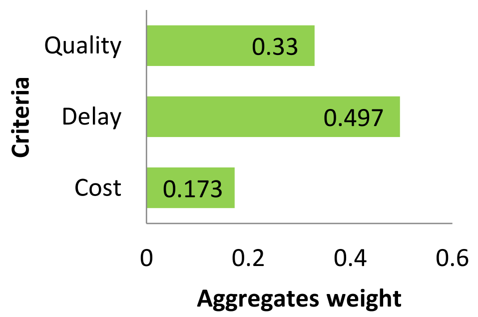


Figure 13: Case 4 aggregate weights sensitivity variation

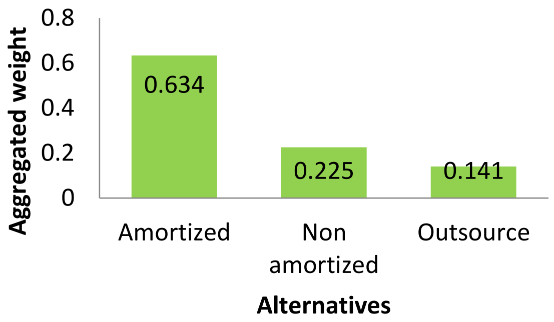


Figure 14: Case 5 sensitivity analysis results

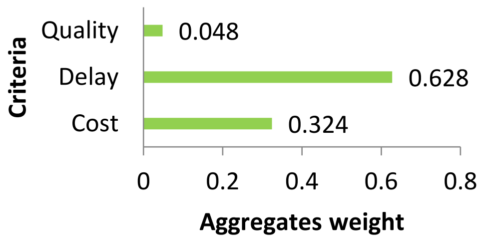
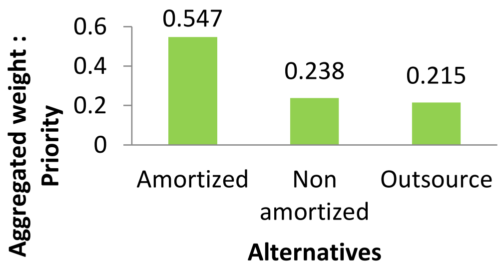


Figure 15: Case 5 aggregate weights sensitivity variation



Tables

Table I: Comparative analysis with recent papers

Paper	Purpose	Scope	Methodology
Govindan and Al-Ansari (2019)	Develop a network simulation model comprising of spatially-distributed and autonomous learning agents	Network-based applications having economic implications to enhance food production systems	Simulation and reinforcement learning
El Raoui *et al*. (2018)	Time-dependent vehicle routing problem with time windows	Distributing perishable foods in urban areas.	ABM-GIS simulation
Martins-Turner *et al*. (2020)	Vehicle routing problem	Case study of food retailing industry	Agent-based transport simulations
Sufiyan *et al*. (2019)	Evaluation of supply chain performance	Food supply chain	Hybrid MCDM technique
Buyukselcuk (2019)	Determine the right cold chain logistics firm	Cold chain in food industry	Hybrid MCDM
Segura *et al*. (2019)	Quantifying the Sustainability of Products and Suppliers	Food distribution companies	MCDM model

Table II: Saaty random index

n	1	2	3	4	5	6	7	8	9	10	11	12
RI	0.00	0.00	0.058	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48

Table III: Criteria description

Criteria	Sub-Criteria		Reference
	Designation	Description and supportive literature	
Cost ©	C1	Fixed costs of the vehicle including depreciation, insurance. Precisely for food industry, this might include the cost of buying or renting refrigerated trucks	Martins-Turner and Nagel (2019), Wang *et al*. (2017)
	C2	Variable costs of distance and time a vehicle is on tour. In the literature, when modeling sustainable food grain supply chain distribution system, it has been argued that variable transportation costs were considered	Martins-Turner and Nagel (2019), Mogal *et al*. (2019)
Delay (D)	D1	Transit lead time. Lead time denotes the time required to complete processes. It has been outlined that the emissions and the lead time are impacted in food transport by the location of distribution centres and retailers	Esteso *et al*. (2018), Gharehgozli *et al*. (2017)
	D2	Shipments planning lead time. In fact, it has been discussed that due to the quick deterioration of perishable food products, proper production, inventory, and shipping planning are crucial	Pratap *et al*. (2022)
	D3	Carriers' delays. It has been debated that logistics should worry transport carriers since perishable goods complicate matters further due to timing and environmental constraints	Pal and Kant (2019)
Quality (Q)	Q1	Responsiveness quality. Food firms are exploring collaboration opportunities with supply chain partners to ensure supply chain efficiency and responsiveness	Tsimiklis and Makatsoris (2019)
	Q2	Consistent error free transits. It has been shown that during distribution, spillage is among the food losses along the value chain	Delgado *et al*. (2021)

	Q3	Condition quality. For instance, in the globalized cold chain, the perishable food distribution is challenging in terms of handling requirements, such as humidity and temperature to decrease food spoilage rate during transportation	Tsang *et al.* (2018)

Table IV: Forecast of shipment frequency per week

City	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13
A	1	2	2	2	2	2	1	2	3	2	2	1	1
B	1	1	1	2	1	1	1	1	1	1	2	1	1
C	1	1	1	1	1	0	1	1	1	1	1	1	1
D	3	4	4	6	5	3	4	5	6	6	6	4	2
E	3	4	3	5	7	3	4	5	5	6	7	3	2
F	1	1	1	1	1	1	1	1	2	1	2	1	1
G	0	1	1	0	0	0	0	0	0	1	0	0	0
H	2	2	2	2	1	1	1	2	3	2	2	2	1
I	0	1	1	1	1	0	1	1	1	1	1	0	1
J	1	2	2	2	1	1	2	2	3	3	3	2	2
K	1	1	1	2	1	1	1	2	2	2	2	2	2
L	2	3	3	3	3	2	3	3	5	4	5	3	2
M	1	1	1	1	1	1	0	1	1	1	1	1	1

Table V: Total costs of distribution shipments [Moroccan Dirham]

City	Non amortized	Amortized	Outsourcing
A	1155,72	711,37	1500,00
B	1647,62	1094,85	1700,00
C	144,02	307,46	800,00
D	1425,48	920,41	1700,00
E	1765,16	1184,31	2500,00
F	1913,07	1837,77	2700,00
G	2180,10	2129,55	3500,00
H	1208,41	1062,50	2000,00
I	881,17	702,92	1200,00
J	1250,35	1110,20	2000,00
K	2698,88	2704,15	4500,00
L	1273,20	1135,98	2300,00
M	2203,63	2158,96	3000,00

Table VI: Scale description

Numerical rating	Preferences
1	Weak
2	Weak to moderate
3	Moderate
4	Moderate to strong
5	Strong
6	Strong to very strong
7	Very strong
8	Very strong to extremely strong
9	Extremely strong

Table VII: Table of demand distribution

<table>
<tr><td colspan="2">Distribution</td><td>normal</td></tr>
<tr><td colspan="2">Expression(mean; standard deviation)</td><td>(0,252 ; 0,0892)</td></tr>
<tr><td colspan="2">Square error</td><td>0,068361</td></tr>
<tr><td rowspan="4">Chi Square Test</td><td>Number of intervals</td><td>5</td></tr>
<tr><td>Degrees of freedom</td><td>2</td></tr>
<tr><td>Test statistic</td><td>37,6</td></tr>
<tr><td>Corresponding p-value</td><td>0,005</td></tr>
</table>

Table VIII: Goal aggregate pair-wise and weights for level 2

	C	D	Q	Weights	Inconsistency
C	1	6	5	0.729	0,08
D	1/6	1	2	0.163	
Q	1/5	½	1	0.109	

Table IX: Cost aggregate pair-wise and weights for level 3

	C1	C2	Weights	Inconsistency
C1	1	2	0.667	0
C2	1/2	1	0.333	

Table X: Delay aggregate pair-wise and weights for level 3

	D1	D2	D3	Weights	inconsistency
D1	1	5	6	0.688	0,34
D2	1/5	1	7	0.248	
D3	1/6	1/7	1	0.064	

Table XI: Quality aggregate pair-wise and weights for level 3

	Responsiveness quality	Consistent error free transits	Condition quality	Weights	Inconsistency
Responsiveness qualit	1	4	7	0.673	0,21
Consistent error free transits	¼	1	7	0.267	
Condition quality	1/7	1/7	1	0.061	

Table XII: Cost aggregate pair-wise and weights for level 4

	Outsourcing	Amortized	Non amortized	Weights	inconsistency
Fixed Cost					0,05
Outsource	1	2	1	0.413	
Amortized	1/2	1	1	0.260	
Non amortized	1	1	1	0.327	
Variable Cost					0,87
Outsource	1	8	2	0.661	
Amortized	1/8	1	4	0.208	
Non amortized	1/2	¼	1	0.131	

Table XIII: Delay aggregate pair-wise and weights for level 4

	Outsourcing	Amortized	Non amortized	Weights	Inconsistency
SKU transit lead time					0,35
Outsource	1	1/6	1/6	0.066	
Amortized	6	1	6	0.717	
Non amortized	6	1/6	1	0.217	
Shipments planning lead time					0,42
Outsource	1	¼	¼	0.093	
Amortized	4	1	7	0.712	
Non amortized	¼	1/7	1	0.195	
Carriers delays					0,35
Outsource	1	1/5	1/6	0.075	
Amortized	5	1	5	0.679	
Non amortized	6	1/5	1	0.247	

Table XIV: Quality aggregate pair-wise and weights for level 4

	Outsourcing	Amortized	Non amortized	Weights	Inconsistency
Responsiveness quality					0,42
Outsource	1	1/6	1/6	0.064	
Amortized	6	1	7	0.735	
Non amortized	6	1/7	1	0.201	
Consistent error free transits					0,21
Outsource	1	1/3	1/3	0.131	
Amortized	3	1	4	0.622	
Non amortized	3	¼	1	0.247	
Condition quality					0,42
Outsource	1	1/6	1/6	0.064	
Amortized	6	1	7	0.735	
Non amortized	6	1/7	1	0.201	