Selecting the Sustainable Fresh Food Surface Transport Array Using Analytic Hierarchy Process

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Abstract. The present study investigates the various arrays of the sectors involved in the logistic of fresh food transportation and distribution, considering the sustainability of the overall process, applying the AHP technique. The focus was on Brazil's fresh food distribution centers and how it is distributed in large cities. The criteria applied in two levels were selected from the literature, and the judgment was made by three experts using an online AHP platform. The final computation was considered the best array with a very high (90.4%) degree of agreement between the participants. The choice of Local food represented 72.1% in the concept of high sustainability. Choosing local foods must not be feasible in large countries or in countries that depend on food imports. However, for fresh food production, the local food production benefits go beyond economic costs, as it helps reduce greenhouse gas emissions, improve the carbon footprint of consumers, encourage sustainable agriculture, and have the shortest traceability.

Keywords: Food logistics, food distribution, food supply chain.

1 Introduction

There are various initiatives to reduce the number of intermediaries in the food supply chain and geographically relocate production and consumption [1-2]. These initiatives share the idea of meeting the many criteria of a sustainable food system. The expansion of the local food chains concept allows the renewal of the relations between the city and country [3]. Within this idea, the environmental impact is taken into account for potential tradeoffs in overall sustainability aspects [4].

Although climate change can be related to other GHG (Nx, NOx, HC, CO) emissions to the environmental impact in food supply chains [5], carbon dioxide emission has been intensely used to estimate the impact in several developed countries [5-6]. Other ways of evaluating environmental impact are the use of the Life Cycle Assessment

(LCA) approach [7], the water footprint [8], the food miles concept [9], and the energy efficiency [10].

The transport of fresh food in Brazil occurs from the producing region to regional distribution centers (Ceasa). Those distribution centers are usually located in large urban areas in each state. The fresh food supply chain is essential for management efficiency and effectiveness, given the complexity of dealing with this product. There is a substantial increase in distribution obstacles due to difficulties in ensuring product quality [11].

The analytical hierarchy process (AHP) is a multi-criteria decision-making methodology that includes qualitative information with the available quantitative data. AHP is a method for decision-making in complex environments in which various criteria are arbitrated in prioritizing and choosing alternatives. It transforms a complex problem into a multi-level hierarchical structure of objectives, criteria, sub-criteria, and alternatives [12]. AHP has been applied to numerous fields of knowledge, including project selection, transportation, and manufacturing [13-15]. AHP is a valuable tool for backing decision-making, mainly when professionals deal with complex and collaborative systems [16].

The present study aimed to evaluate the various arrays of the sectors involving the logistic of fresh food transportation and distribution considering the sustainability of the process, applying the AHP technique.

2 Material and Methods

The present study was carried out in two stages. First, we collected information regarding how the fresh food supply chain actors are related and the options available to have separate arrays. Second, a multi-criteria method (AHP) was applied to select the most sustainable array arrays of fresh food transportation and distribution.

The overall approach had the goal to check some alternatives to decrease the environmental impact on the logistic of the fresh food distribution in Brasil (Figure 1).

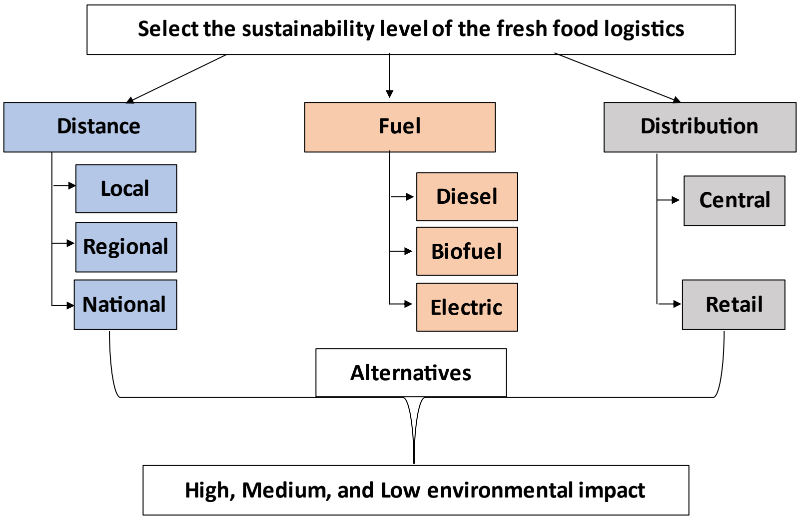

Fig. 1. Schematic of data processing used in the present study containing the criteria and alternatives.

The three first-level criteria were the Distance (from the production area to the distribution center), the Fuel (used in the transportation both in the production area to the city), and the Distribution (related to the product transportation distribution center to the retail). The second level in the distance criterion, we considered the sub-criterion of how far the food production was from the distribution center as Local (when close to the distribution center), Regional (when the farms are relatively within the same region of the distribution center), and National (when the production area is distant from the distribution center).

A set of pairwise comparison matrices (A; Eq. 1) was built. Each element on an upper level was used to compare the elements in the level below [ ] Saaty. The decision of relative weights (wi) of all pairs of the n elements are included as a number (a_{ij}) in a square matrix A (the comparison matrix):

$$A = (a_{ij})\ (i, j=1,2,3,4...n) \quad (1)$$

where $a_{ij} = w_i/w_j$ and $a_{ij} = 1/a_{ji}$.

The parameters for the pairwise comparison followed a 1–9 scale [12], where: 1 = not a priority; 2 = no to moderate priority; 3 = moderate priority; 4 = moderate to high priority; 5 = high priority; 6 = high to very high priority; 7 = very high priority; 8 = very high to greatest priority; 9 = highest priority. The weight was given to the (i, j)th position of the pairwise comparison matrix selected to support comparisons within a restricted range with sufficient sensitivity. The reciprocal of the appointed number was given to the (j, i)th position. The highest eigenvalue (λmax) was used to determine the consistency index (CI), shown in Eq. (2).

$$CI = (\lambda_{max} - n) / (n-1) \quad (2)$$

where CI = consistency index; λ_{max} = highest eigenvalue; and n = dimension of the matrix.

The matrix is entirely consistent when CI = 0, but results are acceptable when CI ≤ 0.1. The weights of element i were compared to element j and assigned to the (i, j) th position of the pairwise comparison matrix within a limited range with sufficient sensitivity.

Three experts were selected to judge the criteria and were assigned the task using the online software Business Performance Management Singapore (BPMSG) [17]. It is a web-based tool to support rational decision-making based on the AHP. It allows defining a hierarchy of criteria for a decision problem, calculating priorities, and evaluating a set of decision alternatives against those criteria. Most information on the selected criteria was learned from cited references described in the current literature [2-5,18].

3 Results and Discussion

The AHP group consensus was very high (90.4%). The scores shown in Figure 2 are the matrix results when computing the degree of importance of each selection criterion.

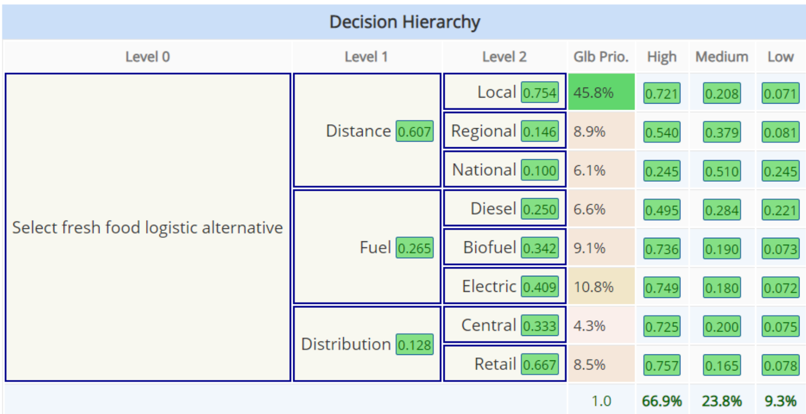

Fig. 2. Scores were found on the different criteria in the different levels used to select the food logistic alternative for the best sustainable solution.

The most sustainable fresh food array was Local food (75.4%), followed by Retail (66.7%), Electric fuel source (40.9%), and Biofuel (34.2%). The remaining alternatives were all below this percentage. The choice of Local food represented 72.1% in the concept of high sustainability. The Electric truck result represented 74.9% in the concept of high sustainability, and the Distribution Retail was 75.7%, while Central was 72.5%.

Apparently, the most significant difference in accounting for sustainability concept is the Distance that appears to be the most important criterion.

Figures 3 present the pairwise comparisons between the tested alternatives. They were associated with the criteria used to select the most sustainable array of choices during fresh food transportation.

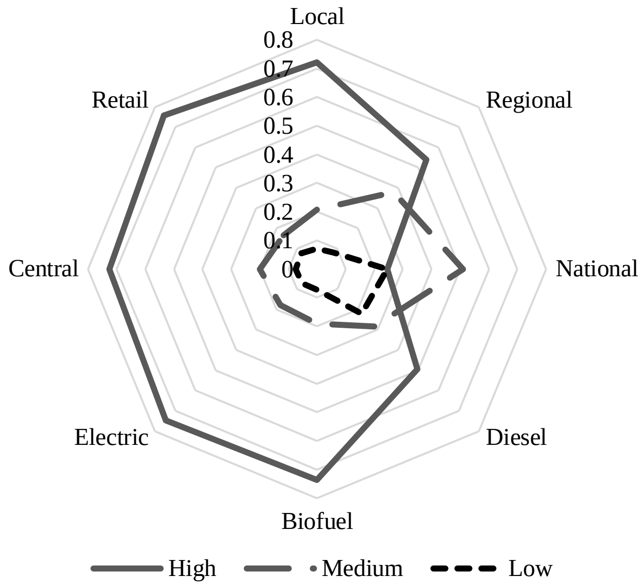

Fig. 3. The pairwise comparisons between the tested alternatives with the answer of the group judgment.

Less polluting fuels and locally produced food, which supply retail and food distribution centers, are better choices to ensure food security (access and availability and rural development), less environmental impact of transport, and socio-economic impacts. In this study, the results showed that the decision making regarding the choices are justified by the higher level of sustainability for fresh food logistics, with higher percentages for local food, taking into consideration the distance that is one of the main factors in choosing the type of fuel in food logistics.

The relationship between fuel type and distribution depends on the supply of fuels and the distance and volume transported to distribution centers and retail [18]. A limitation concerning electric fuel sources is the low supply, mainly in regions with fewer inhabitants or cities that are further away from large centers and less developed. This scenario may change with the development of technologies that contribute to energy security by reducing dependence on fossil fuels implemented for rural and urban economic development. The choices made for food distribution with more sustainable criteria contribute to this vision of rural and urban development less dependent on fossil fuels and local food supply [7,10]. The justification for choosing local foods is the benefits that go beyond economic costs, help to reduce greenhouse gas emissions, improve the carbon footprint of consumers, encourage sustainable agriculture, and have the shortest traceability.

4 Conclusions

Future distribution of food supply systems should consider the overall arrangement of demand and supply on sustainability grounds. New technologies should support the application of the concepts to legitimate the UN 2030 agenda.

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