STM JOURNALS

International Journal of
Industrial and Product Design Engineering

Volume 4, Issue 1, 2026
January—June
DOI (Journal): 10.37591/IJIPDE

https://journals.stmjournals.com/ijipde

Research IJIPDE

# Supply Chain Design Considering Social and Environmental Risks

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***Abstract***

*The aim of the research is to design a supply chain taking into account social and environmental risks. In this research, an attempt was made to present a model that, by considering variables close to the real world, simultaneously considers cost and sustainability issues for designing a meat supply chain network, including locating facilities, using technology in them, how products flow in the network, etc. In order to examine the performance of the model and genetic algorithm with non-dominated sorting, six indicators have been considered. These criteria are the number of Pareto solutions, the distance from the ideal solution criterion, the coverage area criterion, the spacing criterion, and the maximum extent criterion. The algorithm execution time criterion is considered to compare the computational speed. The validity of the model and algorithm presented for solving the problem was measured. According to the results obtained, it can be seen that by reducing the delivery time of goods and raw materials to achieve fresh and quality meat products, the cost increases and the environmental impacts increase due to the construction of factories and food hubs and the selected product distribution system. Considering multiple objective functions provides decision makers with the ability to understand how much an increase in some objective functions will lead to a decrease in other objectives. This will lead to better analysis and decision-making in current environments.*

**Keywords:** Supply chain, meat products, social and environmental risks

## INTRODUCTION

Supply chain management is usually faced with a large volume of physical structure of the supply chain network and uncertainties, which will lead to a complex decision-making activity. Supply chain management usually requires various decisions.

In a competitive environment, managing relationships between Suppliers and customers in the supply chain will be more essential for competitive advantage. Closer and more coordinated relationships will create greater dependence on the productive factors of poultry and aquaculture production, which will lead to exposure of resources to risks associated with the supply side of the supply chain.

The mass production and consumption of meat, poultry and aquaculture has increased significantly due to the growth and development of technology and population growth. Meat production has created direct environmental pressure on fertile areas, including the deforestation of 6.6 million hectares of forest between 2004 and 2014 (INPE, 2016). This issue, along with the lack of sufficient meat supply and its high price, has created a negative reaction in society and among meat

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Received Date: February 12, 2026
Accepted Date: February 26, 2026
Published Date: March 16, 2026

Citation: Farid Baghparvar, Mohammad Taghipour. Supply Chain Design Considering Social and Environmental Risks. International Journal of Industrial and Product Design Engineering. 2026; 4(1): 35–43p.

consumers. Such realities necessitate greater coordination and information exchange between components of the meat supply chain to reduce costs and environmental and social risks. Therefore, sustainability aspects are increasingly playing a role in the strategy of meat supply chains to prevent environmental and social risks.

In a competitive environment, managing relationships between Suppliers and customers in the supply chain will be more essential for competitive advantage. Closer and more coordinated relationships will create greater dependence on the productive factors of poultry and aquaculture production, which will lead to exposure of resources to risks associated with the supply side of the supply chain.

The increase in meat prices in the country, distribution problems, and the inability to meet demand due to the imbalance between meat production and demand have had negative effects on the country. Lack of attention to the environmental and social impacts of meat production at different stages of production, distribution, and customers has currently created problems in society, which has resulted in, in addition to increasing meat prices, environmental problems, and negative social impacts. The application of supply chain principles and concepts has been increasingly used to deal with social and environmental consequences, but evidence on the application of supply chain management in meat industries with a view to social and environmental impacts along with reducing related costs is scarce. In this study, the main sources of social and environmental risks in the meat supply chain and strategic measures in supply chain design to manage such risks have been identified. Various studies in the meat supply chain indicate the negative consequences resulting from the successive actions of stakeholders who have made meat production through deforestation, inadequate fodder, and increased transaction costs. Therefore, identifying social and environmental risks is essential for proper supply chain design. In this study, based on the concerns about the environmental and social impacts of economic activities, national needs and existing goal-setting in meat production and distribution management, as well as the gaps in the relevant literature, the issue of designing a meat supply chain network has been discussed. In this study, the level of impact of these risks on strategic decisions, along with the costs of creating a supply chain, has been attempted to make decisions by looking at the social, environmental and cost dimensions [1–4].

It is worth noting that environmental aspects should be controlled due to the strong connection between meat producers and the natural resources used. Managing environmental and social aspects on farms such as pesticide use, water pollution due to hormone use, deforestation, occupational health and safety and human resources can directly affect other characteristics of the final product such as quality, food safety and costs (Natarnicola et al., 2012). [5] The connection between these issues and meat production necessitates the management of social and environmental issues alongside costs in the supply chain. Social and environmental aspects can affect several factors in the supply chain, including the reputation of organizations. The reputation of organizations is negatively affected due to irresponsible social and environmental practices in the supply chain, leading to changes in consumer behavior in the short term and a decrease in market share in the long term. Social and environmental factors affect organizational reputation among consumers, which can lead to a loss of position among competitors (Rochrich et al., 2014). [6]

Among the issues in the field of food supply chain management is the management of risk and cost in meat supply chains. Regarding risks, risks and costs

In such supply chains, it should be borne in mind that various social and environmental problems and concerns such as deforestation and job creation and labor costs can disrupt the relationship between meat producers in agricultural areas in the hands of environmental organizations and institutions used for raising livestock and poultry, as well as end consumers. The agricultural sectors producing fodder and animal feed on the one hand and livestock, poultry and aquaculture farmers on the other hand are engaged in expanding access to land through deforestation and the use of chemical and biological agents, which attract the attention of different segments of society to social and environmental issues. Meanwhile, with the increase in transaction costs in the production and supply chain of meat products, the increase in the price of feed and human resources, the increase in the costs of constructing and operating facilities, the costs of supplying meat, and ultimately its final price, increases.

In the current research, an attempt is made to present a model that considers both cost and sustainability issues for designing a meat supply chain network, including the location of facilities, the use of technology in them, how products flow in the network, etc., by considering variables close to the real world. In this research, mathematical modeling of a three-level meat supply chain is discussed. The variables that influence supply chain performance that are focused on in this research include average consumer demand and the diversity of demand and products. In the second stage of the proposed model of this research, an attempt is made to present the indicators and influential variables in the form of a mathematical model with the aim of reducing costs and social and environmental risks in the meat supply chain. Then, by solving the model using metaheuristic methods, the answers obtained from the model are evaluated.

## RESEARCH PROBLEM AND ITS IMPORTANCE

By reviewing the articles and research that the researcher has done so far. It was found that there is a suitable research space for researchers in the field of designing a meat supply chain with multiple objectives. In fact, the relationship between these levels in the meat supply chain management sector has not been investigated, considering the agricultural context for providing livestock fodder. Given that similar studies have only dealt with, livestock farming and slaughterhouses, considering a network with complete levels of (1) livestock farmers (2) slaughterhouse centers (3) distribution centers along with routing - locating their facilities, considering the diversity of meat products and multiple objectives, is the problem facing this research.

This research aims to minimize the risks and hazards resulting from the establishment of places and routing with multi-attribute decision-making methods in the social and environmental dimension, which create cost reduction, as well as prevent the languages from deforestation and the use of agricultural lands to provide fodder, and also model the economic dimension of cost reduction through multi-objective mixed integer linear programming.

Supply chain design requires determining the location and technology of facilities and relevant routes in the supply chain network, which has cost implications. In terms of social and environmental risks, supply chain design involves risks depending on the level of land used and the level of social expectations met, which are affected by the decisions made in the chain design. Considering the aforementioned effects, an assessment of the level of risk can be made and finally the level of the objective function is determined in this aspect [7, 8].

## RESEARCH QUESTION

This research seeks to present a mathematical model for designing the supply chain of livestock, poultry and aquatic animals with the aim of reducing costs and social and environmental risks and answering the following question:

### Main Question

What will be the contribution of considering social and environmental risks in addition to the costs of establishing and operating the supply chain of meat products in the design of the aforementioned supply chain to meet the sustainability requirements in today's society according to the definition of sustainability provided?

### Sub-questions

Is it possible to reduce social and environmental risks in addition to reducing transportation and construction costs?

 

Is it possible to use agricultural land to cover the fodder needed by livestock and poultry and aquatic animal feed, considering the agricultural capacity available?

What is the share of purchasing fodder and feed for livestock, poultry and aquatic animals from abroad?

What are the types of facilities created in potential locations?

What are the routes that create the least cost?

Considering the reality of the data and the research environment, are the results obtained usable and applicable?

**RESEARCH METHOD**

In this research, after determining the general framework of the research problem, the articles on designing the supply chain of livestock, poultry and aquatic animals and the existing literature in this field are reviewed, and issues related to meat supply are reviewed, and problem-solving methods are examined in order to determine and measure the parameters affecting the design of the meat supply chain. Then, in the second step, using mathematical modeling methods, the problem of designing the supply chain of meat products is modeled with multiple objectives. In the next step, according to the results of the background investigation and mathematical modeling stages, appropriate solution methods are selected and designed with the characteristics of the problem. In the fourth step, using different problem samples, the problem model is solved and the results are examined, and if necessary, a number of random problems are generated to validate the proposed algorithm. In the next step, the validity of the proposed algorithm for solving the problem is measured, and if possible, the solving power of the algorithm is compared with accurate methods. Finally, after confirming the validity and workability of the proposed solution method, a summary and conclusion of the research are made, and the field of future research in solving the research problem is determined.

**BACKGROUND RESEARCH**

Other research includes the following: Taghipour(2015) [7] .Implementation of Software-Efficient DES Algorithm. In another study Taghipour (2018), [8] The impact of working capital management on the performance of firms listed in Tehran Stock Exchange (TSE). In another study Khalilpour (2018), [1] The impact of accountant's ethical approaches on the disclosure quality of corporate social responsibility information an Islamic perspective in Iran. In research studied The Problem Solving of Bi-objective Hybrid Production with the Possibility of Production Outsourcing through Imperialist Algorithm, NSGA-II, GAPSO Hybrid Algorithms(Hoseinpour2021), [3] In another study Hassan Beigi (2025), [2] Presenting a Fuzzy Mathematical Programming Model for Allocating and Scheduling Parts in a Flexible Manufacturing System (FMS) and the Impact of Repairs and Maintenance on Product Quality.

**In another study Ghandehari (2025), [4] Extended Producer Responsibility in the Apparel Industry**

An Agent-Based Simulation Incorporating Physical and Emotional Product Durability. This study examines the impacts of Extended producer responsibility (EPR) on product life extension and market dynamics. It investigates the relationship between the physical and emotional durability of products in the apparel supply chain, highlighting the importance of the secondary market in prolonging product life and value. By understanding the connections among producers, consumers, and the secondhand market, the study aims to develop a practical approach that helps planners derive optimal synergistic solutions, considering the needs of consumers, ecological considerations, and the economic factors within the apparel market.

**Methods**

The interactions among consumers, producers, and the government are demonstrated through agent-based simulations across five scenarios. The market includes various groups of consumers to represent its heterogeneous nature. The simulation, conducted in NetLogo, models the behavior of both producers and buyers in the context of government intervention.

**Results**

Simulation results indicate that EPR policies, combined with government interventions such as incentives, penalties, and regulations, can effectively promote the management of products at the end of their life cycle. In scenarios that utilized incentives, producers were more likely to buy and sell secondhand products, reducing the production of new items and increasing recycling rates. These results underscore the critical importance of collaboration among the government, the public, and producers to implement EPR policies successfully.

**Conclusion**

Effective implementation of EPR policies requires government market intervention calibration. When the government applies a reward-and-penalty system to enforce EPR, product waste is reduced, and producer profitability surpasses other scenarios.

## MUTATION AND CROSSOVER

The operators of the non-dominated sorting genetic algorithm used in this problem include crossover and mutation. In this research, a parallel method has been used in using the operators. In this method, two operators separately select chromosomes from the entire population. In this algorithm, two-point crossover has been used. Roulette wheel method has been used to select the type of crossover and random mutation with a rate of 0.3 has been used for the mutation operator.

## CASE STUDY

The example problem under study includes a supply chain network that produces meat product (S2) and two potential slaughterhouse locations (B.R) are considered for the extraction and production of meat products. There is a breeder with only one technology. Only the production of meat product is considered, which is supplied by a livestock breeder located at location M. Two distribution locations are established at locations (LO). The demand at each distribution location is given in Table (1).

It is also possible to install a hub facility at location A, where there is no product warehouse and it is related to cross-functional activities. The construction costs of each supply chain center and their capacity are given in Table (2).

**Table 1.** Annual demand per distribution location (in tons).

| Demand | Market |
|---|---|
| [200 100] | LO |
| [300 150] | LO |

**Table 2.** Costs of constructing livestock maintenance and breeding centers (in dollars) and their capacity.

| Construction cost centers(Millions | Construction Cost Centers (Millions) | Costs of product storage and livestock breeding(5) | Capacity |
|---|---|---|---|
| *M* | ۱۵۰ | Livestock farming(500) | 1000livestock |
| *B* | ۹۰ | ۱۰۰ | 200livestock |
| L | ٤۰ | ۲۰ | Products from 50 livestock |
| L | ٤۰ | ۲۰ | Products from 50 livestock |
| *2* | ٤۰ | ۳۰ | Products from 50 livestock |
| *A* | ۲۰ | ۱۰ | Products from 100 livestock |

**Table 3.** Distance between supply chain centers (in kilometers).

| 0 | L | A | R | B | |
|---|---|---|---|---|---|
| | | | ۱۲۰۰ | ۲۰۰۰ | M |

 

| | | | | | |
|---|---|---|---|---|---|
| ٧٠٠ | ٦٠٠ | ١٥٠٠ | | | B |
| ٦٠٠ | ٧٠٠ | ٤٠٠ | | ` | R |
| ٢٠٠ | ٤٠٠ | | | | A |

**Table 4.** DOE factor levels.

| Level 2 | Level 1 | Factors | Row |
|---|---|---|---|
| 2E3 | 1E3 | P | ١ |
| 0.7 | 0.9 | P | ٢ |
| 0.005 | 0.05 | Pm | ٣ |

Each animal takes an average of 90 days to raise and one day to process in the slaughterhouse. The costs are such that the meat must reach the distribution centers every week. The meat storage time is also 5 days, and in case of delay, a penalty of $200 is imposed on the supply chain system. The distance between the centers is also given in Table (3).

Livestock raised from location M is transported to slaughterhouses located at R and B by a combination of different types of vehicles. Meat products can be transported via slaughterhouses to distribution centers located at and O. From R, meat products can be transported by truck and rail. Finally, meat products can be transported by truck and by air from the slaughterhouses to the hub located at 8 and then by trucks to the distribution centers.

## SIMULATION OF NSGA-II RESULTS

The NSGA-II algorithm is largely dependent on the control parameters population size, hybrid probability operator and mutation probability n. Bagchi and Deb proposed a design of experiments approach using NSGA-II experimental implementations. To select these parameters, which are validated by statistical tests, we plan a 2-factorial experiment arrangement.

For each combination of parameters, we generate a total of 8 combinations of 5 randomly generated initial sequences and test them in each experiment, the required number of experiments. In order to reduce the variance in each of the 8 factorial experiments, these 5 initial sequences are left unchanged. A more robust approach is to generate 5 problems randomly and select a random initial sequence for each of these problems. During the execution of the NSGA-II algorithm, for each combination of parameters, a total of 8 combinations of these problems and initial sequences are left unchanged. The parameter combination for a problem of a given size is determined by taking the lowest observed value for the generation time after 300 runs for each combination of parameters and for each experimental run, then averaging these values over 5 runs.

Select the parameter that gives the lowest average production time. Table 4 shows the two levels of factors considered in the DOE

In this study, we will examine small, medium, and large-scale problems. The problem dimensions under consideration are supply chains with 2 livestock breeding centers, 4 slaughterhouse centers, 4 distribution centers, and a hub for small-scale problems. Supply chains with 2 livestock breeding centers, 8 slaughterhouse centers, 8 distribution centers, and 1 hub for medium-scale problems. Supply chains with 2 livestock breeding centers, 16 slaughterhouse centers, 16 distribution centers, and 1 hub for large-scale problems. In this table, D indicates the number of slaughterhouses and L indicates the number of distribution centers. Next, we will examine the performance of the genetic algorithm with non-dominated sorting using simulated problems (Table 5).

**Table 5.** DOE factor levels and problem dimensions.

| Pm | Parameters P | P | Dimensions of the problem | The size of the problem | Numbers |
|---|---|---|---|---|---|

 

| | | | | | |
|---|---|---|---|---|---|
| 0.05 | 0.9 | 1E3 | Small | ID2L | ١ |
| 0.05 | 0.7 | 2E3 | Small | 2D3L | 2 |
| 0.005 | 0.7 | 1E3 | Small | 4D4L | 3 |
| 0.05 | 0.9 | 1E3 | Average | 5D6L | 4 |
| 0.005 | 0.9 | 2E3 | Average | 6D8L | 5 |
| 0.05 | 0.7 | 1E3 | Average | 8D8L | 6 |
| 0.05 | 0.9 | 1E3 | Big | D 10 L 9 | 7 |
| 0.05 | 0.7 | 2E3 | Big | D 12 L 10 | 8 |
| 0.005 | 0.9 | 1E3 | Big | D 14 L 14 | 9 |
| 0.005 | 0.7 | 1E3 | Big | D 16 L 16 | 10 |

## PERFORMANCE REVIEW OF NSGA-II ALGORITHM

In order to check the performance of the genetic algorithm with non-negative sorting, six indicators have been considered. These criteria are the number of Pareto solutions (NOS), the distance from the ideal solution (MID), the coverage level of the sets (CS), the spacing criterion (S) and the maximum extent criterion (MD).

The NOS criterion indicates the number of Pareto optimal solutions that can be found in each algorithm. An algorithm that produces a larger number of solutions is better. Here, for the sake of simplicity, we have extracted 50 solutions for each problem for both GAMS and NSGA-II methods.

The MID criterion is used to calculate the average distance of the Pareto solutions from the ideal solution, which here are the solutions obtained by the GAMS software. The lower this criterion, the higher the efficiency of the algorithm.

In order to obtain the value of 2, the distance between the NSGA-II algorithm solutions and the corresponding GAMS solutions is considered for each objective function (Table 6).

The coverage level is the most important criterion for comparing two multi-objective algorithms. The set coverage criterion (CS(AB) is the proportion of answers from B that are weakly defeated by answers from A.

## CONCLUSION

In this study, all aspects of the perishable goods supply chain are considered by introducing three objective functions to minimize the cost of supply chain design and environmental impacts and maximize the freshness of the meat to customers. The proposed model of this study was used for sample problems. The sample problems considered are explained to examine the impact of multiple objectives on decision-making. The results of the study show the effect of objective functions on each other.

According to the results obtained, it can be seen that by reducing the delivery time of goods and raw materials to achieve fresh and quality meat products, the cost increases and the environmental impacts increase due to the construction of factories and food hubs and the selected product distribution system.

Considering several objective functions provides the ability for decision-makers to find out by what extent an increase in some objective functions will result in a decrease in other objectives. This will lead to better consideration and decision-making in current environments.

**Table 6.** Comparing the results of solving problems with GAMS and GA software

| **The whole issue** | **solution method** | **Number of answer criterionپارتو** | **Distance measure From the ideal answer** | **The criterion of the coverage level of the** | **Spacing criteria** | **The most extensive criterion** | **Execution time benchmark الگوریتم** |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | **collections** | | | |
| 1 | GAMS | There is no difference | 0 | 0 | ٤٥ | ٩٣٣ | (min) 5 |
| | NSGA-II | There is no difference | 42 | 0٣ | 48 | ٩٢١ | (min) 4 |
| 2 | GAMS | There is no difference | 0 | 0 | 49 | ٩٩٧ | (min) 12 |
| | NSGA-11 | There is no difference | ٦٧ | 0٣1 | 52 | ٩٨۵ | (min) 8 |
| 3 | GAMS | There is no difference | 0 | 0 | 54 | ١١٧٩ | (min) 23 |
| | NSGA-II | There is no difference | ٨٣ | ٤٦٥٠ | 56 | ١٠٩٤ | (min)15 |
| 4 | GAMS | There is no difference | 0 | 0 | 58 | ١٢٦٢ | (min) 52 |
| | NSGA-II | There is no difference | ٨١٤ | .٤٩٥ | 59 | ١١٥٤ | (min) 26 |
| 5 | GAMS | There is no difference | 0 | 0 | 60 | ١٣٤٤ | (.hrs) 1.02 |
| | NSGA-II | There is no difference | ١٣٩ | 01٧ | 61 | ١١٩٧ | (min) 42 |
| 6 | GAMS | There is no difference | 0 | 0 | 63 | ١٥٢٦ | (.hrs) 1.3 |
| | NSGA-II | There is no difference | ١٢٢۶ | .10 | 67 | ١٢١٣ | (min) 58 |
| 7 | GAMS | There is no difference | 0 | 0 | 70 | ١٤٩٨ | (.hrs) 2.08 |
| | NSGA-II | There is no difference | ٢٩٩٧ | 0٧ | 85 | ١٢١٩ | (.hrs) 1.2 |
| 8 | GAMS | There is no difference | 0 | 0 | 92 | ١۵٩١ | (.hrs) 2.3 |
| | NSGA-II | There is no difference | ٣٩٩٦ | 001 | 101 | ١٢٣۵ | (.hrs) 1.6 |
| 9 | GAMS | There is no difference | 0 | 0 | 105 | ١٦٧٣ | (.hrs) 2.6 |
| | NSGA-II | There is no difference | ٤٩٣٦ | .٨٣ | 107 | ١٣١۵ | (.hrs) 2.05 |
| 10 | GAMS | There is no difference | 0 | 0 | 110 | ٢٧۵۵ | (hrs) 3.1 |
| | NSGA-II | There is no difference | ٦٤٩٨ | .410 | 120 | ١٣٥٧ | (.hrs) 2.4 |

The results show the diversity of transportation means for distributing meat products in the network based on different objective functions. In addition, the existence of the hub has helped in faster delivery of products to customers. The resulting changes in the distribution network and the centers opened can show the importance of different functions in decision-making. In addition, greater distances will also lead to the selection of different transportation options.

Other results of this research include the method of demand coverage in Sebekah, where we are looking to reduce costs in network design and distribution, maximum coverage is achieved to avoid facing shortages of goods. However, in other objective functions, without considering this component in decision-making, demand coverage is proportionate to environmental and freshness goals, and subsequently a volume of meat products reaches customers that does not lead to delays in shipping and does not have environmental impacts.

## FUTURE SUGGESTIONS

The following are suggested for future studies.

Developing the concepts of environmental impacts on supply chain network design and planning decisions In this regard, this thesis has only considered the effects of fuel and electricity consumption on human health. Therefore, these topics can be expanded by examining other effective items in the supply chain on human health, consumption resources and the impact on the earth.

Considering sources of uncertainty in modeling and scenario building in time series methods and considering correlation between uncertainties In this study, definite demand has been considered. However, scenarios can be studied and included in decision-making by using time series and applying other sources of uncertainty using the study of correlation between them.

Applying other methods to solve the MILP model of a multi-objective stochastic supply chain We solved the model by developing NSGA-II meta-heuristic algorithms. However, the development of other meta-heuristic algorithms can also be effective in this regard.

 

Using fuzzy theory to study fuzzy uncertainties in the model In this thesis, fuzzy uncertainty has not been studied. However, having goals such as environmental impacts can be studied in the form of fuzzy numbers. Therefore, future studies can focus on this issue.

Development of modeling with more constraints on the meat product supply chain and transportation methods In the proposed model, extensions to the problem constraints such as considering product expiration constraints or developing transportation methods and modes can be proposed. In general, other things can also be applied in modeling.

**Author contributions**

Conceptualization, MT and FB; methodology, FB and MT; software, FB and MT; validation, MT and FB; formal analysis, FB and MT; investigation, FB and MT; resources, MT and FB; data curation, FB and MT; writing—original draft preparation, MT and FB; writing—review and editing, FB and MT; visualization, FB and MT; supervision, FB and MT; project administration, FB and MT. All authors have read and agreed to the published version of the manuscript.

**Conflict of interest**

The authors declare no conflict of interest.

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