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Design a Mathematical Planning Approach to Optimize the Supply Chain Taking Into Account Uncertainties In Distributors

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Abstract. With the globalization of markets and increasing competition in global markets, the attempts of organizations to survive in this market has increased and has resulted in the emergence of the philosophy of Supply Chain Management. There is uncertainty in the reliability of supply chain facilities for reasons such as natural disasters, terrorist attacks, labor errors, and weather conditions. Therefore, when making strategic decisions, the system will continue to operate with minimal damage. Over the course of this study, the uncertainty of supplier layers in the supply chain has been modeled. To meet that aim, the

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issue of supply chain, including producers, warehouses, suppliers and consumers are considered. To calculate the cost of breakdowns due to the non-functioning of distributors, the scenario-building method has been utilized. Finally, the desired model is solved with Gomez software and the results are presented. The result of the study demonstrate the efficiency of this model in the facility location decision-making in supply chains.

Keywords: Capacity levels, network design, probability of occurrence, scenario building, supply chain.

1. Introduction

Supply Chain Management (SCM) is regarded as the set of approaches and practices that are utilized for the integrated management of supply chain members (manufacturers, suppliers, retailers, and customers) with the aim of cost-saving and attaining enhanced customer service levels [1-5]. With the expansion of industries throughout the world and the intensification of markets competition, the survival of businesses is not merely depending on only the economic production and distribution of product. However, it also depends on the identification of the most desirable locations for performing these production and distribution actions [6-8]. Doubtless, among of the most substantial yet tough challenges in SCM as a production-distribution modeling approach is how to determine where to place the facilities and how to allocate demand points to these facilities at each level of the chain so as to guarantee the optimal flow of services and goods [7,9,10]. In recent years, location and allocation studies have emerged as one of the key elements in the success and survival of industrial units and supply chains. Facility location is a subfield of the industrial engineering science that revolves around how facilities should be placed in order to achieve goals such as cost reduction or performance improvement in a system or network like a supply chain [11-15]. Supply chains tend to be exposed to a wide range of risks, which make it very difficult for managers to make big decisions like where to build or move their facilities. Indeed, the reliability of supply chain facilities can be affected by many uncertain factors such as natural disasters, terrorist attacks, labor issues, weather conditions, etc. [16,17]. Therefore, when making strategic decisions in this regard, one must carefully consider the uncertainties that are common in real-world situations so that the system can continue functioning with minimal damage when they occur [18-23].

2. Literature Review

Regarding supply chains, uncertainty implies changes in profitability and fulfillment resulted from unforeseen events and in how challenging it is to take decisions while there is a lack of unambiguousness in the supply chain, indicating we have no way of knowing the impact and status of the actions we could take. Supply chain uncertainties tends to be classified into three main classes: supply layer uncertainties (likelihood of disruption/breakdown in facilities contributing to gratifying customer demand), demand layer uncertainty (randomness of customer demand), and middle layer uncertainties (randomness of the time or cost of transport between two points) [9,13,19]. Supply layer uncertainties are the only group of uncertainties that, despite their low occurrence probability, have a great impact on the geography of the chain, as they may require

reallocating demand to other production or distribution centers [15]. In recent years, facility location in supply chains under uncertainty has been the subject of numerous theoretical and case studies, some of which are reviewed below. Petrovic et al. [11] developed a fuzzy model for designing a supply chain in an uncertain environment, where the goal was to determine optimal inventory levels and order quantities for each product over a limited time period in order to achieve an acceptable performance level at a reasonable cost for the entire supply chain. Tsiakis et al. [17] developed a two-stage stochastic programming model for the problem of designing a multi-product multi-echelon supply chain with uncertain demand. They proposed an integrated integer linear programming model for determining the number, location, and capacity of distribution centers, routes, and material production rates so that the annual network cost is minimized. Chen et al. [2] developed a model for multi-period, multi-stage, multi-product planning of a production-distribution system. In this model, the goal was to maximize the profit of every member of the supply chain and customer service level, maintain a safe inventory level, and ensure fair profit distribution. This model was formulated as a multi-objective nonlinear mixed-integer programming model and solved using the fuzzy set theory approach. Wang and Shu [18] developed a decision model based on the genetic algorithm that minimizes the inventory cost of the supply chain subject to the constraints defined for the target fill rate of the finished product. They used the fuzzy set theory to formulate uncertainties in customer demand, processing times, and delivery times. Handfield et al. [4] used the fuzzy set theory to develop a model for (Q, R) inventory policies in uncertain supply chains and presented a method for calculating the total cost of this inventory system through defuzzification. The goal of this study was to find logical ways to approximate uncertain parameters and conduct the (Q, R) policy calculations accordingly in order to minimize the total annual cost. Peidro et al. [9] proposed a multilevel, multi-period, and multi-product fuzzy mathematical programming model for designing supply chains with supply, demand, and process uncertainties. In this study, uncertain data were modeled in the form of triangular fuzzy numbers. They formulated the problem as a fuzzy mixed-integer linear programming model where tactical supply chain planning is properly considered. In another study, Peidro et al. [10] formulated a similar model with the difference that uncertain data were modeled as trapezoidal fuzzy numbers (instead of triangular). Scaparra and Church [13] developed a model for the allocation of limited resources to a series of existing facilities such that the total weighted distance between facilities and demand points in the worst-case scenario is minimized. Goli and Malmir [3] introduced a mathematical model for the problem of location and routing in crisis situations. In this study, the objective function was defined as the minimization of the latest service time. Yolmeh and Saif [19] provided a mathematical model for designing a supply chain with assembly-disassembly line balancing in an uncertain environment. In the model of this study, location and distribution decisions are made simultaneously with assembly-disassembly line balancing decisions. These researchers developed an enhanced decomposition method for solving this problem.

In the literature on the subject of supply chain uncertainties, studies have been generally more focused on uncertainties in the demand and middle layers of supply chains and less on uncertainties in the supply level. Also, very few of these studies have the scenario-building approach to this subject. Therefore, in this study, we have developed a model for designing a three-level supply chain structure with supply level uncertainty using the scenario-building approach. For this purpose, we have used the supply chain design problem for the supply chain networks that consist of manufacturers, warehouses, distributors, and

customers. The scenario building approach has been used to determine the cost imposed by supply disruptions (facility breakdowns). In this study, the average cost of these disruptions is computed by multiplying the probability of occurrence of each scenario by the cost of transportation between different layers in that scenario and then summing up the products. In the proposed reliable facility location model, the goal is to select a subset of candidate locations for placing manufacturers, warehouses, and suppliers such that the total chain cost is minimized with the uncertainties in the operation of suppliers in different scenarios taken into consideration. The remainder of this article is organized into two sections. The first section describes the designed model and its variables and properties, explains how it is solved with GAMS, and presents the numerical results, and the second section presents the research conclusions.

In the majority of studies carried out in the arena of location and allocation, the parameters are deemed to be deterministic. In those studies that have examined uncertainty, the focus has been on uncertainty in demand. Hence, the proposed model in this study intends to to minimize the chain costs by considering the possibility of facility breakdowns (supply disruptions) utilizing the scenario-building approach.

In the current study, it is assumed that the supply chain consists of plants, warehouses, distributors, and customers. The variables used in the model formulation include binary variables that determine whether a certain facility (plants, warehouses, and distributors) is constructed at a certain node (1 if yes, 0 if no). The model also includes several decision variables that determine, for each facility constructed between two nodes, the fraction of demand that is fulfilled by each distributor, the fraction of distributor inventory that is supplied from each warehouse, and the fraction of warehouse inventory that is supplied from each plant. The sets used in the problem formulation include the sets of potential sites for plants, distributors, and warehouses, the set of customer points, the set of scenarios for facility breakdowns, and the set of capacity levels for potential plants, warehouses, and distribution facilities. The model parameters include the demand size, the probability of occurrence of each scenario, product types, fixed construction costs for plants, warehouses, and distributors, and cost of transport between plants, warehouses, distributors, and customers. The results of the study demonstrated the effectiveness of the proposed model, and consequently, this study can make a desirable contribute to the arena of arena of Supply Chain Optimization cindering Uncertainties In Distributors.

3. Material and Methods

The proposed model makes use of the following parameters and variables.

3.1. Model sets

I: Set of customer points
J: Set of potential sites for distributors
M: Set of potential sites for warehouses
K: Set of potential sites for plants
S: Set of scenarios for facility breakdowns
R: Set of capacity levels for potential distribution facilities
L: Set of capacity levels for potential warehouses

H: Set of capacity levels for potential plants

3.2. Model parameters

a_i: Demand of customers in region i
b_j^r: Capacity of distribution facility j at the capacity level r
t_m^l: Capacity of warehouse m at the capacity level l
e_k^h: Capacity of plant k at the capacity level h
nf(s): Number of facility breakdowns in scenario s
D: Minimum customer demand that must be fulfilled
qq: Probability of facility breakdown
F_j^r: Cost of constructing distribution facility j with the capacity level r
W_m^l: Cost of constructing distribution facility m with the capacity level l
G_k^h: Cost of constructing distribution facility k with the capacity level h
C_{1ij}: Cost of transporting each unit of product from distribution facility j to customer i
C_{2jm}: Cost of transporting each unit of product from warehouse m to distribution facility j
C_{3mk}: Cost of transporting each unit of product from plant k to warehouse j

3.3. Model variables

$U_j^r = 1$ if a distribution facility with capacity r is constructed at site j, =0 otherwise
$N_m^l = 1$ if a warehouse with capacity l is constructed at site m, =0 otherwise
$VV_k^h = 1$ if the plant with capacity h is constructed at site k, =0 otherwise
X_{ij}^s : The fraction of the demand of consumer i that is fulfilled by distributor j in scenario s
Z_{jm}^{rs} : The fraction of the inventory of distributor j that is supplied from warehouse m in scenario s
y_{mk}^{ls}: The fraction of the inventory of warehouse m that is supplied from plant k in scenario s
$Q_{s,j}$=1 if $j \in F'_s$, =0 otherwise

3.4. Objective function and constraints

$$min\ f_1 = \left[\sum_{j\in J}\sum_{r\in R} F_j^r U_j^r + \sum_{k\in K}\sum_{h\in H} G_k^h V_k^h + \sum_{m\in M}\sum_{l\in L} W_m^l N_m^l\right] + \sum_{s\in S} P_s \left(\sum\sum C_{1ij}\, a_i X_{ij}^s + \sum_{r\in R}\sum_{j\in J}\sum_{m\in M} C_{2jm}\, b_j^r Z_{jm}^{rs} + \sum_{l\in L}\sum_{m\in M}\sum_{k\in K} C_{3mk}\, t_m^l y_{mk}^{ls}\right) \quad (1)$$

$$\sum_{j\in J} X_{ij}^{s} \le 1 \qquad \forall i \in I, s \in S \qquad (2)$$

$$X_{ij}^{s} \le \sum_{r\in R} U_j^r \, Q_{s,j} \qquad \forall i \in I, j \in J, s \in S \qquad (3)$$

$$\sum_{i\in I} a_i X_{ij}^{s} \le \sum_{m\in M}\sum_{r\in R} b_j^r \, Z_{jm}^{rs} \qquad \forall j \in J, s \in S \qquad (4)$$

$$\sum_{m\in M} Z_{jm}^{rs} \le U_j^r \qquad \forall j \in J, r \in R, s \in S \qquad (5)$$

$$\sum_{j\in J}\sum_{r\in R} Z_{jm}^{rs} \, b_j^r \le \sum_{l\in L} T_m^l \times N_m^l \qquad \forall m \in M, s \in S \qquad (6)$$

$$\sum_{k\in K} y_{mk}^{ls} \le N_m^l \qquad \forall m \in M, l \in L, s \in S \qquad (7)$$

$$\sum_{m\in M}\sum_{l\in L} T_m^l \, y_{mk}^{ls} \le \sum_{h\in H} e_k^h \, V_k^h \qquad \forall k \in K, s \in S \qquad (8)$$

$$\sum_{j\in J} X_{ij}^{s} \, a_i \le D \qquad \forall i \in I, s \in S \qquad (9)$$

$$\sum_{j\in J}\sum_{r\in R} b_j^r \, Z_{jm}^{rs} \le \sum_{k\in K}\sum_{l\in L} T_m^l \, y_{mk}^{ls} \qquad \forall m \in M, s \in S \qquad (10)$$

$$\sum_{r\in R} U_j^r \le 1 \qquad \forall j \in J, \qquad (11)$$

$$\sum_{l\in L} N_m^l \le 1 \qquad \forall m \in M \qquad (12)$$

$$\sum_{h\in H} v_k^h \le 1 \qquad \forall k \in K \qquad (13)$$

$$Y_{mk}^{ls} \ge 0, Z_{jm}^{rs} \ge 0, X_{ij}^{s} \ge 0 \qquad (14)$$

$$V_k^h \in \{0/1\}, N_m^l \in \{0/1\}, U_j^r \in \{0/1\} \qquad (15)$$

The first part of the objective function tries to optimize the costs of constructing distribution facilities, plants, and warehouses, and its second part minimizes the average cost of facility breakdowns, which is determined by multiplying the probability of occurrence of different scenarios by the cost of transportation between different layers. Constraint (2) ensures that shipments remain smaller than the capacity of customers. Constraint (3) states that if a distributor is present and working (not broken down or disrupted), it can meet customer demand. Constraint (4) states that demand cannot be satisfied beyond the capacity of distribution facilities. Constraint (5) makes sure that the fraction of warehouse inventory that is shipped to distributors is at most 1. Constraint (6) ensures that distribution demand cannot be met beyond the capacity of warehouses. Constraint (7) states that the fraction of plant inventory that is shipped to warehouses is at most 1. Constraint (8) ensures that the warehouse demand cannot be met beyond the capacity of plants. Constraint (9) makes sure that each customer receives at least D units of

product. According to Constraint (10), the quantity of products leaving each warehouse must be less than or equal to the quantity that has been supplied to that warehouse.

4. Results and Discussion

This section presents the results of a numerical example solved by the proposed model. In this example, the chain consists of 2 plants, 3 warehouses, 4 distributors, and 5 customers with different capacity levels and different construction and transportation costs. A number of scenarios have been considered for distribution facility breakdowns. The purpose of the solution process is to determine how each level of the chain should be constructed and determine the distribution of inventories in distribution facilities and warehouses such that customer demand is satisfied at minimum cost. The values of problem parameters in this example are provided in the following tables (Tables 1-6).

Table 1. Capacity of distribution facilities, warehouses, and plants

b(r,j)	1	2	3	4	t(l,m)	1	2	3	e(h,k)	1	2
1	10	15	20	30	1	20	15	18	1	48	45
2	18	10	21	15	2	21	24	19	2	50	53

Table 2. Cost of constructing distribution facilities, warehouses, and plants

F(r,j)	1	2	3	4	W(l,m)	1	2	3	G(h,k)	1	2
1	110	120	140	110	1	180	190	150	1	250	220
2	95	100	110	95	2	130	120	100	2	230	190

Table 3. Cost of transporting each unit of product

C_1(i,j)	1	2	3	4	C_2(j,m)	1	2	3	C_3(m,k)	1	2
1	2	5	4	8	1	5	6	7	1	10	9
2	6	9	4	2	2	3	4	9	2	8	6
3	5	6	8	10	3	6	2	8	3	5	9
4	8	3	7	6	4	6	7	9			
5	10	8	3	2							

Table 4. Demand size, number and probability of facility breakdowns in each scenario, and minimum required level of demand satisfaction

	1	2	3	4	5
a(i)	20	17	13	19	20
nf(s)	1	2	4	3	2
qq	0.7	0.3			
D	2	1			

After solving the model with GAMS, the following solutions were obtained for the above problem.

Table 5. Constructed distribution facilities, warehouses, and plants

U_j^r	1	2	4	N_m^l	3	V_k^h	2
2	2	2	1	2	2	1	2

Table 6. Fraction of distribution facility and warehouse inventories that is shipped downstream for demand satisfaction

X_{ij}^s	1	2	4	Z_{jm}^s	3	y_{mk}^s	2
1.1	0.471	0.14	0.024	1.73	0.241	1.4	0.371
1.2			0.191	0.94	0.142	2.5	0.341
1.3	0.067			1.4	0.133	3.3	0.263
1.4		0.059		2.1	0.111	4.3	0.263
1.5			0.043	2.4	0.200	5.3	0.263
2.1	0.083			3.1	0.278		
2.2			0.050	4.4	0.333		
2.3	0.067			5.2	0.500		
2.4			0.059				
2.5			0.043				
3.1	0.083						
3.2	0.050						
3.3	0.067						
3.4	0.059						
3.5	0.043						
4.1			0.083				
4.2			0.050				
4.3			0.067				
4.4			0.059				
4.5			0.043				
5.1		0.083					
5.2		0.050					
5.3		0.067					
5.4		0.059					
5.5		0.043					

As shown in Table (5), in this example, plant No. 2, warehouse No.2, and distributors No.1, 2, and 4 must be constructed. Table (6) shows the fraction of warehouse and distribution facility inventories that is shipped downstream to satisfy customer demands. For example, in the column (Z_{jm}^{rs}), (1, 4) means that, in the first scenario, 0.133 of the inventory of distributor No.4 is supplied from the third warehouse. In the column (X_{ij}^s), (3, 5) means that, in the fifth scenario, 0.059 of the demand of customer No.3 is supplied from distributor No.2.

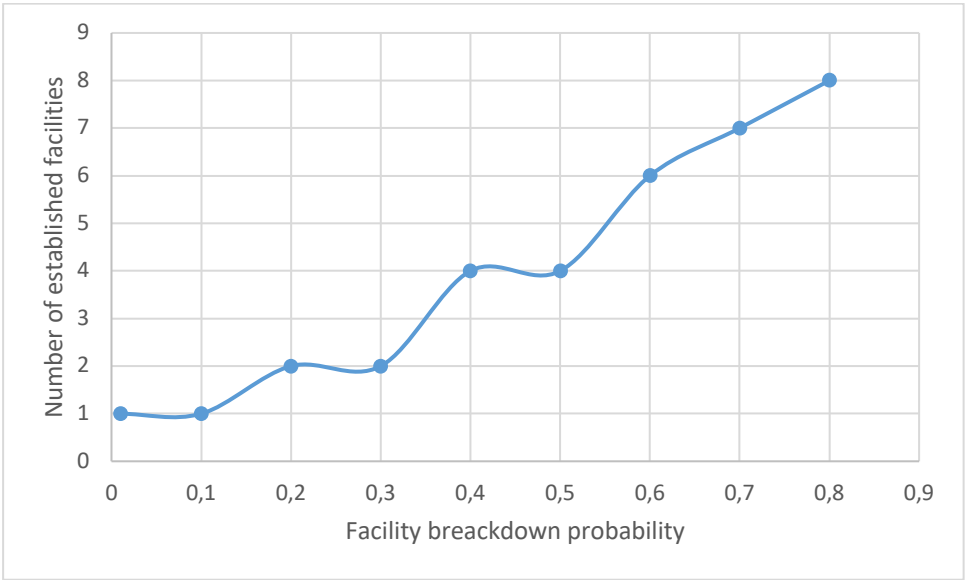


Figure 1. Relationship between the facility breakdown probability and the number of facilities constructed

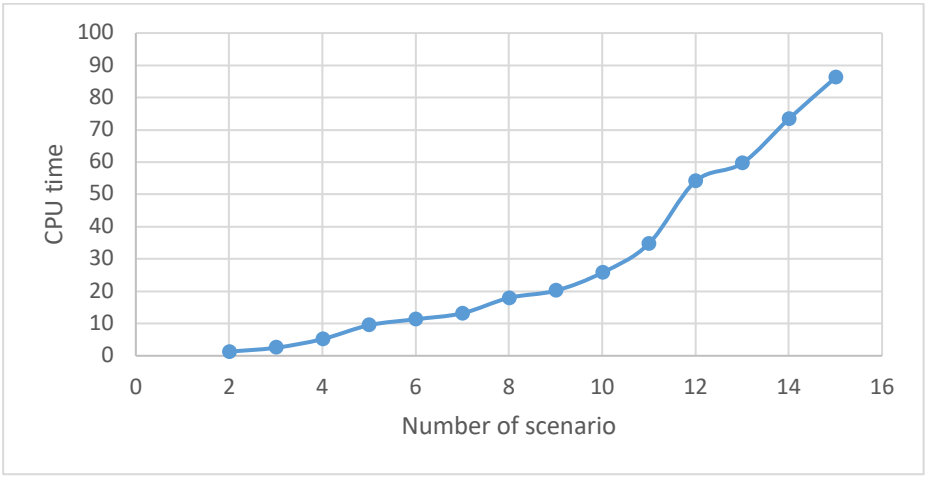


Figure 2. Relationship between the number of scenarios and the solution time

Figure (1) shows the relationship between the facility breakdown probability and the number of facilities constructed. It can be seen that as the facility breakdown probability increases, the chain needs to construct more facilities to make sure that demand is met as required. Figure (2) shows the relationship between the number of scenarios and the solution time. Naturally, considering a greater number of scenarios prolongs the solution process.

Overall, as globalization consolidation continue, supply risk could expand as a substantial source of overall business risk. Thus, steps should be taken by companies alleviate the undesirable effect of supply chain disruptions and guarantee goods are still received and shipped on time. In today's economy, the mere thing that is certain is that companies will face more supply challenges and risks compared to the past. Applying the right means, they can evaluate their hazards and handle them efficiently.

Overall, companies should utilize all the accessible external data to more desirable evaluate external uncertainty and examine their internal data to decrease the costs related to internal uncertainty, getting the best use of, and integrating, the manufacturing process knowledge with analytic competencies. The better we comprehend the present, the better we could predict the future.

5. Conclusion

In this study, it was attempted to develop a model for designing supply chains with uncertainty in the operationality of distributors (supply disruptions) with the utilization of the scenario-building method. Given the variety of uncertainties that may impact the operations of a supply chain, it could be challenging for managers to make a decision as to where to build facilities. The present study presented a multi-level supply chain design model with capacity constraints for facility location decision-making in supply chains where distribution facilities are susceptible to break down and solved it with the GAMS software. This model could be put into action in order to promote the field of supply chain management.

In future studies, it may be worthwhile to consider the possibility of simultaneous breakdowns in manufacturers and distributors, use Markov chains to determine the probability of transition from one state to another, and use meta-heuristic algorithms to solve the problem.

References

[1]. Campbell J.F., Integer programming formulations of discrete hub location problems, *European Journal of Operational Research*, **72***,* 2, 1994, 387-405.

[2]. Chen C.L., Wang B.W., Lee W.C., Multiobjective optimization for a multienterprise supply chain network, *Industrial & Engineering Chemistry Research*, **42**,9, 2003, 1879-1889.

[3]. Goli A., Malmir B., A covering tour approach for disaster relief locating and routing with fuzzy demand, *International Journal of Intelligent Transportation Systems Research*, **18***,* 1, 2020,140-152.

[4]. Handfield R., Warsing D., Wu X., (Q, r) Inventory policies in a fuzzy uncertain supply chain environment, *European Journal of Operational Research*, **197***,* 2, 2009, 609-619.

[5]. Huang M., Dong L., Kuang H., Jiang Z.Z., Lee L.H., Wang, X., Supply chain network design considering customer psychological behavior-a 4PL perspective, *Computers & Industrial Engineering*, **159**, 2021, 107484.

[6]. Langevin A., Riopel D., (Eds.), *Logistics systems: design and optimization* (Vol. 2). Springer Science & Business Media, 2005

[7]. Murthy D.N.P., Solem O., Roren T., Product warranty logistics: Issues and challenges, *European Journal of Operational Research*, **156***,* 1, 2004, 110-126.

[8]. Pahlevan S.M., Hosseini S.M.S., Goli A., Sustainable supply chain network design using products' life cycle in the aluminum industry, *Environmental Science and Pollution Research*, 2021, 1-25.

[9]. Peidro D., Mula J., Poler R., Verdegay J.L., Fuzzy optimization for supply chain planning under supply, demand and process uncertainties, *Fuzzy sets and systems*, **160***,* 18, 2009, 2640-2657.

[10]. Peidro D., Mula J., Jiménez M., del Mar Botella M., A fuzzy linear programming based approach for tactical supply chain planning in an uncertainty environment, *European Journal of Operational Research*, **205***,* 1, 2010, 65-80.

[11]. Petrovic D., Roy R., Petrovic R., Modelling and simulation of a supply chain in an uncertain environment, *European journal of operational research*, **109***,* 2, 1998, 299-309.

[12]. Pike D.F., Cohen M.A., Performance Characteristic Stochastic Integrated Production Distribution System, *European Journal of operational research*, **68**, 1993, 23-48.

[13]. Scaparra M.P., Church R.L., A bilevel mixed-integer program for critical infrastructure protection planning, *Computers & Operations Research*, **35***,* 6, 2008, 1905-1923.

[14]. Shen Z.J.M., Daskin M.S., Trade-offs between customer service and cost in integrated supply chain design, *Manufacturing & service operations management*, **7***,* 3, 2005, 188-207.

[15]. Snyder L.V., Daskin M.S., Reliability models for facility location: the expected failure cost case, *Transportation science*, **39***,* 3, 2005, 400-416.

[16]. Li Y., Li X., Shu J., Song M., Zhang K., A general model and efficient algorithms for reliable facility location problem under uncertain disruptions, *INFORMS Journal on Computing*, **34***,* 1, 2022, 407-426.

[17]. Tsiakis P., Shah N., Pantelides C.C., Design of multi-echelon supply chain networks under demand uncertainty, *Industrial & engineering chemistry research*, **40***,* 16, 2001, 3585-3604.

[18]. Wang J., Shu Y.F., Fuzzy decision modeling for supply chain management, *Fuzzy Sets and systems*, **150***,* 1, 2005, 107-127.

[19]. Yolmeh A., Saif U., Closed-loop supply chain network design integrated with assembly and disassembly line balancing under uncertainty: an enhanced decomposition approach, *International Journal of Production Research*, **59***,* 9, 2021, 2690-2707.

[20]. Rubashkina Y., Galeotti M., Verdolini E., Environmental regulation and competitiveness: Empirical evidence on the Porter Hypothesis from European manufacturing sectors, *Energy Policy*, **83**, 2015, 288-300.

[21]. Baghizadeh K., Zimon D., Jum'a L., Modeling and optimization sustainable forest supply chain considering discount in transportation system and supplier selection under uncertainty, *Forests*, **12,** 8, 2021, 964.

[22]. RezaHoseini A., Noori S., Ghannadpour S.F., Integrated scheduling of suppliers and multi-project activities for green construction supply chains under uncertainty, Automation in Construction, **122**, 2021, 103485.

[23]. Nguyen T.D., Nguyen-Quang T., Venkatadri U., Diallo C.,Adams M., Mathematical programming models for fresh fruit supply chain optimization: a review of the literature and emerging trends, AgriEngineering, **3**, 3, 2021, 519-541.

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