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RESEARCH ARTICLE Open Access

Designing an Optimal Selection Model of Transportation Network in A Multi-level Supply Chain Using Game Theory

Mahmood Darvishsefat [1], Javad Rezaeian [2]*, Mohammad Mahdi Pourpasha [3]

Abstract
Modern organizations' strategy is reducing inventory, production cycle time, transportation cost, quality cost, while increasing competitiveness to maximize its benefits. We present a comprehensive multi-level model of a supply chain consisting of several simultaneous stakeholders in a systematic way. In order to achieve the lowest transportation cost at different levels, the model also provides lowest costs of purchase and production by considering the costs of maintenance, supply shortages and shortage, for all the involved parties. In addition, a competition in the context of a game to select the optimal situation between the stakeholders of the supply chain has been considered to make the best decision in terms of a participatory game by considering different scenarios. The results of a numerical example showed that the answer provided by the game theory for the value of the objective function was less than the answers of the transport problem, despite the deficit penalty.
Keywords: *Game theory, Multi-level supply chain, Transportation model*

Introduction

In a competitive global market, organizations pay special attention to supply chain management and optimal selection policies. Identifying the most appropriate techniques to inform decision making on supplier's selection to lower the costs and achieve the highest benefit, is one of the most important management challenge in any organization. A successful partnership would be achieved through close collaborative competition between any organization, its customers and suppliers by considering their mutual benefits. To successfully stay in the market, organizations must be knowledgeable in all components of their supply chain. An appropriate supply chain management appreciates that competition is not primarily between organizations, but is between supply chains (Kannan, 2017). Organizations deal with customers who want a high variety of products and services, low cost, high quality, and quick response (Salimi et al, 2020). Optimum supplier selection can strengthen the social and economic structure of a company by minimizing cost and ensuring continuous customer satisfaction (Zimmer et al, 2016). A supply chain refers to the flow of physical goods and associated information from the source to the consumer. Key supply chain activities include production planning, purchasing, materials management, distribution, customer service, and sales forecasting. (Mohammadi et al, 2022) According to the results of a systematic review of 198 studies published between 1995 and 2018, it can be concluded that the entire sustainable aspects of the supply chain are still not fully addressed. (Marzban et al, 2022) The supply chain of a parent company includes there technology groups, namely product, process, and supplier. The parent company should pay adequate attention to the supply chain technological capability in its

1. Ph.D. Candidate in Industrial Management, Department of Management, Firuzkuh Branch , Islamic Azad University, Firuzkuh , Iran
2[*]. Associate Professor, Department of Industrial Engineering, Mazandaran University of Science and Technology, Babol, Iran, (Corresponding Author: j.rezaeian@ustmb.ac.ir)
3. Assistant Professor, Department of Mathematics, Chalus Branch, Islamic Azad University, Chalus, Iran

technology development strategy. (Ehsani et al, 2021)

Supply chain management typically involves several stakeholders, each controlling part of the chain. Multiple stakeholders include recipients of goods or services, the organization as a service provider, employees of the organization, vendors, facilitators, and the governmental bodies. Both suppliers (sellers) and customers create value based on their experience, knowledge, and skills, while customers do it through their experience too (Chakraborty et al, 2020).These stakeholders may pursue different goals. Most of the existing studies focused on optimal design and performance of supply chains using optimization models. In these models, one decision maker is assumed for the entire supply chain to make operational decisions, and optimization, under a one general and unified objective function. As a result, the claimed 'optimal' solutions from centralized models could be non-optimal (or a subset of the optimal solution) or even unacceptable in decentralized or multiple stakeholders' models, as the real interests of each of the stakeholders are not appropriately considered in such centralized models (Lima et al, 2016). Therefore, a comprehensive theoretical model of multi-stakeholder supply chains that considers decisions and interests of stakeholders in a systematic and simultaneous manner is necessary. In this paper, we developed an optimal choice model in transportation networks with multiple stakeholders, through game theory. To achieve the common interests of all stakeholders, the factors of transportation and distribution of goods, between the members of the supply chain, was considered through a model to achieve optimal profit of the parties. Then to choose an optimal mode between the stakeholders of supply chain a competition by the game theory was considered, which led to making the best decision under the conditions of a cooperative game by considering coalitions in different scenarios. The game theory's scenarios were planned to maximize the interests of the parties, and selecting the optimal state.

Literature Review

Jafari considered a supply chain, which included Manufacturer, recycling center and waste depot while assuming one type of recycled waste being used to manufacture a specific product. The customers' demand for the considered product was then determined based on its price. In the study, a manufacturer meets the requirements for a product through two different channels. They can procure the non-recycled waste from the waste depot and then recycles it by themselves or can buy the recycled waste from the recycler. Results indicated that the manufacturer selects each channel as a threshold is met. Moreover, more recyclability rate of the considered waste leads to higher profits for the members. In this research, to provide the waste materials required for producing a product, the game-theoretic approach as well as the concept of the channel-selection were used (Jafari, 2022).

Adabi presented a mathematical model of production routing problem by applying environmental protection policies. The company used as a case study consisted of two independent production and distribution departments. These subsets were managed in a decentralized manner and the two-way communication between them forms a Stackelberg game. The distribution company was the first level decision maker and determined the route for vehicles and the amount of product transfer to each customer. The distributor had two goals, minimization of distribution and maintenance costs while minimizing vehicle emissions. The distribution company could purchase the product from the subsidiary manufacturing company or could provide a replacement product by paying more from other manufacturers; in the latter case, it would receive compensation from the manufacturer. The second subcategory, or the producer, deals with production scheduling with the aim of minimizing production and maintenance costs. The analysis of the numerical results indicated that the desirability of the final decisions from the point of view of the distributor and the producer was sensitive to the cost of the substitute product and the compensation. In addition, the solutions of two-level fuzzy ideal programming method were equal or very close to the anti-ideal solution (Adabi, 2022).

Mahmoudi modeled a sustainable urban transportation network with data envelopment analysis (DEA) and game theory. Using DEA and game theory, two different mathematical models were presented based on the efficiency related to sustainable transportation network such as the selection of transportation infrastructure projects and the construction of streets. Subsequently, factors affecting the stability of urban transportation network were identified and final list of evaluation indicators were selected by using the best-worst ranking method. Genetic meta-heuristic algorithm was used to solve the developed models. The analysis results of computational tests approved the performance of the proposed algorithm (Mahmoudi, 2019).

Chen et al formulated green supply chain with a game theory approach in the hotel industry. The results proved that most hotels have an incentive mechanism for the growth of the green supply chain and hotels with green behaviors are more profitable. The findings can assist governments in formulating effective environmental policies, provide a theoretical avenue in governing green practice, and guide stakeholders to understand the formation and evolution of green development in the hotel industry (Chen et al, 2016). Farjana developed models of an inland waterway transportation network by considering uncertainties. A multi-commodity, multi-period mixed integer linear programming model was proposed to capture the diverse characteristics of the inland waterway transport network. To this end, a two-stage stochastic mixed-integer nonlinear programming model was developed to manage congestion in an inland waterway transportation network under stochastic commodity supply and water level fluctuation scenarios. All the developed models were validated by a real-life case study focusing on the inland waterway transportation network along the Mississippi river (Farjana, 2020). Fengqi and Gao presented a multiple decentralized supply chains optimizing model-using game theory in probabilistic research. In addition, effects of uncertainties in the supply chain with multiple stakeholders were investigated and as a factor against uncertainty, the corresponding optimal strategies based on game theory were presented. The developed model is a game-theory-based stochastic model that integrates two-stage stochastic programming with a single-leader-multiple-follower Stackelberg game scheme for optimizing decentralized supply chains under uncertainty. The resulting model was formulated as a two-stage stochastic mixed-integer bi-level nonlinear program, which can be further reformulated into a tractable single-level stochastic Mixed-integer linear program (Fengqi et al, 2018). Kanan studied the role of multiple stakeholders and the theory of critical success factors (CSF) for a sustainable supplier selection. Through a three-phase methodology, this study examined Indian suppliers by considering the sustainability views of various stakeholders, including employees, customers, researchers, shareholders, and a government environmental officer. The results show that the supplier rankings were highly influenced by CSF's social dimensions (Kanan, 2017).

Research Methodology

In this paper, we present an optimization model of transportation networks under the conditions of multiple stakeholders by using the cooperative game theory in order to coalition and increase the competitive power against competitors. This is to ensure all stakeholders simultaneously secure their interests and achieve the best possible state. A transportation model was assumed that considering the benefits of all stakeholders, which consists of four levels including suppliers, producers, distribution intermediaries and the end consumer. The key factors of distribution of goods among the members of the supply chain is considered. The model optimizes the transportation cost of vehicles in different levels of the chain. The objective function minimizes the costs of purchase, maintenance, shortage as well the storage. Furthermore, a competition in a game framework is presented to choose an optimal mode between the stakeholders of the supply chain. The best decision is subsequently taken in the conditions of a cooperative game by considering different scenarios. Game theory was selected so scenarios would maximize the interests of parties.

Cooperative and non-cooperative game

In Non-cooperative games, all players are independent. Each player needs maximum benefits. This is often problematic. In cooperative games, players cooperate to achieve more benefits instead of competing. They choose strategies with more collective consequences by forming a coalition. The cooperative games model can reduce many national, regional and even international conflicts costs. The cooperative game is denoted by (N.V), where N= {1.2.….n}, V is the characteristic function, which is outcome of each coalition. Every subset of N= {1.2.….n} except { }, (denotes the empty set) forms a coalition called S. The payoff of the coalition S will be equal to the sum of the payoffs of each member of the coalition S. Eq. (1)

$$V(S) = \sum_{i \in S} u_i(a_1 \dots \dots . a_n) \qquad (1)$$

Where $a = (a_1 \dots \dots . a_n)$is the selected strategy of players of coalition S. The goal is to find a coalition whose outcome is equal to the maximum attainable outcome. A coalition with maximum results is desired. Eq. (2)

$$V(N) = \max_a \sum_{i=1}^{n} u_i\ (a) \qquad (2)$$

Credit allocation using Shapley value

A probability is assigned to each coalition member. It is the Shapley value or the strength of that player in the coalition. Eq. (3)

$$\emptyset_i(V) = \sum_{i \in S} \frac{(|s|-1)! \times (n-|s|)!}{n!} \times [\,V(S) - V(S - \{i\})] \qquad (3)$$

Where |s| is the number of coalition members, and [V(S) −V (S− {i})] is the increase of the outcome of the coalition if the member joins it (Asghari et al, 2019). In this paper, according to the number of the supply chain components (including i the number of suppliers, j the number of producers, k the number of distribution centers and l the number of customers), the number of players in the coalition is equal to (i.j.k.l). The number of all possible coalitions is equal to: Eq. (4)

$$2^{(i.j.k.l)} \qquad (4)$$

In this paper, the outcome of each player, V ({i}), is the output of solving transportation model by the coalition condition, and the total value of the coalition is calculated by the Shapley value method. Coalition will create the optimal mode in terms of transportation. It will be determined which coalition will be the optimal mode of transportation model.

Modeling

The purpose of the transportation model is determining the best amount of each product from each supplier to each producer, and from each producer to each distribution center, also from each center to each customer, as well as the lowest delivery cost at all levels of supply chain.

Assumptions

1. Customer deployment centers are predetermined.
2. The centers of deployment of suppliers, manufacturers and distributors are already determined.
3. The number of vehicles is unlimited.
4. Not all distributor or producer are necessarily the same. For example, not every production center can produce every product, or every supplier is only able to provide a certain number of parts.

5. The vehicles between different levels are not necessarily the same.
6. Each vehicle serves only one destination during its journey.
7. At the beginning of the period, distributors and producers do not have inventory.
8. Shortage is allowed to the customer and is considered a lost sale.
9. Every vehicle that is sent from the supplier to the producer or from the producer to the distributor can serve only one different production or distribution center during the day.
10. Each vehicle from the distributor to a customer serves only one customer at a time.
11. Each vehicle from the distributor to the customer can serve different customers during the day, while after serving each customer; it returns to the corresponding center and reloads.
12. A vehicle in a supplier or producer center or a distribution center cannot serve a producer, a distributor, or a customer twice in one day.
13. There is a capacity limit.

Index and sets

i :Supplier index $i \in \{0,1,2,\dots,I\}$
j : Producer index $j \in \{0,1,2,\dots,J\}$
k : Distributor index $k \in \{0,1,2,\dots,K\}$
l : Customer index $l \in \{0,1,2,\dots,L\}$
p : Product index $P \in \{0,1,2,\dots,P\}$
s : Piece index $s \in \{0,1,2,\dots,S\}$
t : Period index $t \in \{0,1,2,\dots,T\}$
α : Vehicle available in the supplier centers index $\alpha \in \{0,1,2,\dots,\alpha\}$
β : Vehicles available in production factories index $\beta \in \{0,1,2,\dots,\beta\}$
γ : Vehicles available in distribution centers index $\gamma \in \{0,1,2,\dots,\gamma\}$

Parameters

q_{as} : Transporting cost of each kilogram of piece s per distance by vehicle α
$q_{\beta p}$: Transporting cost of each kilogram of product p per distance by vehicle β
$q_{\gamma p}$: Transporting cost of each kilogram of product p per distance by vehicle γ
SP_a : Vehicle capacity α in kg
SP_β : Vehicle capacity β in kg
SP_γ : Vehicle capacity γ in kg
W_p : Product weight p in kg
W_s : Weight of piece s in kg
$Capps_{ist}$: Total capacity of supplier i of piece s in period t
$Cappm_{jpt}$: Total capacity of factory j of product p in period t
$Cappd_{kpt}$: Distributor k's total capacity of product p in period t
$Capm_{jt}$: Warehouse capacity of manufacturer j in period t
$Capd_{kt}$: Warehouse capacity of distribution center k in period t
Vol_P : The volume of each product unit p
C_{ist} : Purchasing cost of part s from supplier i in period t
C_{jpt} : Production cost of product p in factory j in period t
d_{ij} : Distance from supplier i to factory j
d_{jk} : Distance from factory j to distributor k
d_{kl} : Distance from distributor k to customer l
dm_{plt}: Customer l's demand for product p in period t
O_{sp} : The coefficient of consumption of part s in product p
$Hor_{\alpha t}$: Working hours of vehicle α in period t
$Hor'_{\beta t}$: Working hours of vehicle β in period t
$Hor''_{\gamma t}$: Working hours of vehicle γ in period t
$fc_{ij\alpha t}$: Fixed cost of sending vehicle α from supplier i to manufacturer j in period t
$fc'_{jk\beta t}$: Fixed cost of sending vehicle β from manufacturer j to distributor k in period t
$fc''_{kl\gamma t}$: Fixed cost of sending vehicle γ from distributor k to customer l in period t
h_{jpt} : Holding cost of each unit of product p in production center j in period t

Variables

V_{jpt} : The amount of production of each product p in production center j in period t

$x_{ij\alpha st}$: The amount of part s transported from supplier i to factory j by vehicle α in period t
$y_{jk\beta pt}$: The amount of product p transported from factory j to distributor k by vehicle β in period t

$$\text{Min Cost} = \text{Min ZZ} \sum_{i}\sum_{j}\sum_{\alpha}\sum_{t} fc_{ij\alpha t} \times U_{ij\alpha t} \quad (5)$$

$$+\sum_{j}\sum_{k}\sum_{\beta}\sum_{t} fc'_{jk\beta t} \times U'_{jk\beta t} \quad (6)$$

$$+\sum_{k}\sum_{l}\sum_{\gamma}\sum_{t} fc"_{kl\gamma t} \times U"_{kl\gamma t} \quad (7)$$

$$+\sum_{i}\sum_{j}\sum_{\alpha}\sum_{s}\sum_{t} (q_{\alpha s} \times w_s \times d_{ij}) \times X_{ij\alpha st} \quad (8)$$

$$+\sum_{j}\sum_{k}\sum_{\beta}\sum_{p}\sum_{t} (q_{\beta p} \times w_p \times d_{jk}) \times Y_{jk\beta pt} \quad (9)$$

$$+\sum_{k}\sum_{l}\sum_{\gamma}\sum_{p}\sum_{t} (q_{\gamma p} \times w_p \times d_{kl}) \times Z_{kl\gamma pt} \quad (10)$$

$Z_{kl\gamma pt}$: The amount of product p transported from distributor k to customer l by vehicle γ in period t
R_{jpt} : Inventory of production center j of product p in period t
h'_{kpt} : Holding Cost of each unit of product p of distribution center k in period t
N_{lpt} : Shortage penalty for customer l of product p in period t
$time_{ij}$: Round trip time from supplier i to manufacturer j
$time'_{jk}$: Round trip time from manufacturer j to distributor k
$time"_{kl}$: Round trip time from distributor k to customer l
R'_{kpt} : Inventory of distribution center k of product p in period t
M_{lpt} : The amount of customer l's missed order of product p in period t

$U_{ij\alpha t}$: Binary variable shows send or not the vehicle α from supplier i to manufacturer j in period t
$U'_{jk\beta t}$: Binary variable shows send or not the vehicle β from producer j to distributor k in period t
$U"_{kl\gamma t}$: Binary variable shows send or not the vehicle γ from distributor k to customer l in period t

The Objective Function

The first, second and third Eq. (5), Eq. (6), Eq. (7) sentences of the objective function calculate the fixed cost of using vehicles (from supplier to manufacturer, from manufacturer to distribution centers and then to customers). The fourth, fifth and sixth Eq. (8), Eq. (9), Eq. (10) sentences are minimizing the transporting cost between the supplier, manufacturer and the distributors. The seventh Eq. (11) sentence is related to the cost of purchasing parts from suppliers and the eighth Eq. (12) sentence is related to the cost of producing products at the manufacture. The ninth and tenth Eq. (13), Eq. (14) sentences also minimized the holding cost of product in the manufacturer and distributor's warehouse. The end Eq. (15) sentence will minimize the shortage cost for the customer.

$$+\sum_{i}\sum_{j}\sum_{\alpha}\sum_{s}\sum_{t} C_{ist} \times X_{ij\alpha st} \quad (11)$$

$$+\sum_{j}\sum_{p}\sum_{t} c_{jpt} \times V_{jpt} \quad (12)$$

$$+\sum_{j}\sum_{p}\sum_{t} h_{jpt} \times R_{jpt} \quad (13)$$

$$+\sum_{k}\sum_{p}\sum_{t} h'_{kpt} \times R'_{kpt} \quad (14)$$

$$+\sum_{l}\sum_{p}\sum_{t} N_{lpt} \times M_{lpt} \quad (15)$$

Model Constraints

These three constraints (16), (17), (18) indicate that a vehicle can be dispatched from the supplier to the factory and from the factory to the distribution centers and from there to the customer multiple times in a day, during the working hours of that day. (Because of the time, limit).

$$\sum_i \sum_j time_{ij} \times U_{ij\alpha t} \leq Hor_{\alpha t} \quad \forall t, \alpha \tag{16}$$

$$\sum_j \sum_k time'_{jk} \times U'_{jk\beta t} \leq Hor'_{\beta t} \quad \forall t, \beta \tag{17}$$

$$\sum_k \sum_l time''_{kl} \times U''_{kl\gamma t} \leq Hor''_{\gamma t} \quad \forall t, \gamma \tag{18}$$

Capacity of the supplier constraint. Eq. (19)

$$\sum_j \sum_\alpha X_{ij\alpha st} \leq Capps_{ist} \quad \forall\, i, s, t \tag{19}$$

Producer's capacity constraint. Eq. (20)

$$V_{jpt} \leq Cappm_{jpt} \quad \forall\, j, p, t \tag{20}$$

Capacity of the distributor constraint. Eq. (21)

$$\sum_l \sum_\gamma z_{kl\gamma pt} \leq Cappd_{kpt} \quad \forall\, k, p, t \tag{21}$$

Capacity of the production center constraint. Eq. (22)

$$\sum_p Vol_P \times R_{jpt} \leq Capm_{jt} \quad \forall j, t \tag{22}$$

Inventory capacity of the distribution center constraint. Eq. (23)

$$\sum_p Vol_P \times R'_{kpt} \leq Capd_{kt} \quad \forall k, t \tag{23}$$

The amount of the factory's product according to the parts received from the supplier. Eq. (24)

$$\sum_i \sum_\alpha X_{ij\alpha st} \geq \sum_p V_{jpt} \times O_{sp} \; \forall\; j, s, t \tag{24}$$

This one is an equilibrium constraint. Eq. (25). The maximum amount of a product sending from a producer to distribution centers in a period is equal to the amount of product received from different factories, plus the inventory of the same product from the previous period.

$$V_{jpt} + R_{jp(t-1)} \geq \sum_k \sum_\beta y_{jk\beta pt} \quad \forall j, p, t \tag{25}$$

This one is an equilibrium constraint too Eq. (26); the maximum supply of a distribution center is equal to the amount of product it receives from different factories plus the amount of inventory from the previous period.

$$\sum_j \sum_\beta y_{jk\beta pt} + R'_{kp(t-1)} \geq \sum_l \sum_\gamma z_{kl\gamma pt} \quad \forall p, k, t \tag{26}$$

Customer demand constraint. Eq. (27)

$$\sum_k \sum_\gamma z_{kl\gamma pt} + M_{lpt} \geq dm_{plt} \quad \forall l, p, t \tag{27}$$

The inventory of a product in a certain period in a production center is the inventory from the previous period plus the amount of production of that product, minus the amount of sending that product to the distribution centers in that period. Eq. (28)

$$R_{jpt} = R_{jp(t-1)} + V_{jpt} - \sum_k \sum_\beta y_{jk\beta pt} \; \forall\; j, p, t \tag{28}$$

The inventory of a product in a certain period in a distribution center is, the previous period inventory plus the amount of that product received from production centers in that period, minus the amount of sending that product to customer centers in that period. Eq. (29)

$$R'_{kpt} = R'_{kp(t-1)} + \sum_j \sum_\beta y_{jk\beta pt} - \sum_l \sum_\gamma Z_{kl\gamma pt} \; \forall\; k, p, t \tag{29}$$

The capacity of the vehicles constraints. Eq. (30), Eq. (31), Eq. (32)

$$\sum_s W_s \times x_{ij\alpha st} \leq SP_\alpha \times U_{ij\alpha t} \; \forall\; i, j, \alpha, t \tag{30}$$

$$\sum_{p} W_p \times y_{jk\beta pt} \leq SP_\beta \times U'_{jk\beta t} \qquad \forall\, j,k,\beta,t \tag{31}$$

$$\sum_{p} W_p \times z_{kl\gamma pt} \leq SP_\gamma \times U''_{kl\gamma t} \qquad \forall\, k,l,\gamma,t \tag{32}$$

Variables: Eq. (33), Eq. (34)

Binary: $U_{ij\alpha t}, U'_{jk\beta t}, U''_{kl\gamma t}$ (33)

$X_{ij\alpha st}, Y_{jk\beta pt}, Z_{kl\gamma pt}, R'_{kpt}, R_{jpt}, M_{lpt.} \geq 0$, Integer (34)

Research Findings

Numerical Example in Small Dimensions

A supply chain consists of two suppliers, one manufacturer, one distributor, and two customers (these are Assumption numbers) Fig.1.

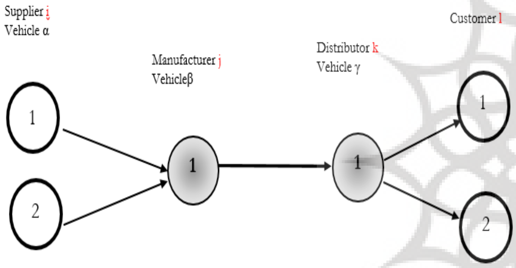

Figure 1. *A four level supply chain*

i : Supplier index = 2
j : Producer index = 1
k : Distributor index = 1
l : Customer index = 2
p : Product index = 1
s : Piece index = 2
t : Period index = 1
α : Vehicle available in the supplier centers index = 1
β : Vehicles available in production factories index = 1
γ ؛ Vehicles available in distribution centers index = 1

Parameters:

$q_{\alpha s}$: Transporting cost of each kilogram of piece s per distance by vehicle α , q_{11}= 200, q_{12}= 300

$q_{\beta p}$: Transporting cost of each kilogram of product p per distance by vehicle β , q_{11} = 250

$q_{\gamma p}$: Transporting cost of each kilogram of product p per distance by vehicle γ , q_{11} = 400

SP_a : Vehicle capacity α in kg: α1 = 25000

SP_β : Vehicle capacity β in kg: β1 = 29000

SP_γ : Vehicle capacity γ in kg: γ1 = 28000

W_p : Product weight p in kg: w1 = 22

W_s : Weight of piece s in kg: s1 = 3, s2 = 6

$Capps_{ist}$: Total capacity of supplier i of piece s in period t ,
$Capps_{111}$ = 600000, $Capps_{121}$ = 550000, $Capps_{211}$ = 550000, $Capps_{221}$ = 600000

$Cappm_{jpt}$: Total capacity of factory j of product p in period t , $Cappm_{111}$ = 350000

$Cappd_{kpt}$: Distributor k's total capacity of product p in period t , $Cappd_{111}$ = 450000

$Capm_{jt}$: Warehouse capacity of manufacturer j in period t , $Capm_{11}$ = 40000

$Capd_{kt}$: Warehouse capacity of distribution center k in period t , $Capd_{11}$ = 70000

Vol_p : : The volume of each product unit p , p1 = 4

C_{ist} : Purchasing cost of part s from supplier i in period t ,
C_{111} = 52, C_{121} = 53, C_{211} = 48, C_{221} = 53

C_{jpt} : Production cost of product p in factory j in period t , C_{111} = 1

d_{ij} : Distance from supplier i to factory j , d_{11} = 89, d_{21} = 139

d_{jk} : Distance from factory j to distributor k , d_{11} = 84

d_{kl} : Distance from distributor k to customer l , d_{11} = 22, d_{12} = 35

dm_{plt}: Customer l's demand for product p in period t , dm_{111} = 44, dm_{121} = 37

O_{sp} : The coefficient of consumption of part s in product p , O_{11} = 1, O_{21} = 1

$Hor_{\alpha t}$: Working hours of vehicle α in period t, Hor_{11} = 480

$Hor'_{\beta t}$: Working hours of vehicle β in period t, Hor'_{11} = 520

$Hor'_{\beta t}$: Working hours of vehicle γ in period t, Hor'_{11} = 540

$fc_{ij\alpha t}$:Fixed cost of sending vehicle α from supplier i to manufacturer j in period t , fc_{1111} = 230, fc_{2111} = 330

$fc'_{jk\beta t}$: Fixed cost of sending vehicle β from manufacturer j to distributor k in period t , fc'_{1111} = 190

$fc"_{kl\gamma t}$: Fixed cost of sending vehicle γ from distributor k to customer l in period t , $fc"_{1111}$ = 145, $fc"_{1211}$ = 245

h_{jpt} : Holding cost of each unit of product p in production center j in period t, h_{111}= 5

h'_{kpt} : Holding Cost of each unit of product p of distribution center k in period t, h'_{111}=5

N_{lpt} : Shortage penalty for customer l of product p in period t , N_{111} = 1530000, N_{211} = 1650000

$time_{ij}$: Round trip time from supplier i to manufacturer j , $time_{11}$ = 38, $time_{21}$= 48

$time'_{jk}$: Round trip time from manufacturer j to distributor k, $time'_{11}$= 48

$time"_{kl}$: Round trip time from distributor k to customer l , $time"_{11}$ = 8, $time"_{12}$= 11

By solving the numerical example with the proposed model using Gams software, the optimal values of the variables will be as follows.

V_{jpt} : The amount of production of each product p in production center j in period t , V_{111} = 81

M_{lpt} : The amount of customer l's missed order of product p in period t, M_{lpt}= (All 0)

R'_{kpt} : Inventory of distribution center k of product p in period t , R'_{kpt}= (All 0)

R_{jpt} : Inventory of production center j of product p in period t , R_{jpt}= (All 0)

$x_{ij\alpha st}$: The amount of part s transported from supplier i to factory j by vehicle α in period t, x_{11111} = 81 , x_{11121} = 81

$y_{jk\beta pt}$: The amount of product p transported from factory j to distributor k by vehicle β in period t , y_{11111} = 81

$Z_{kl\gamma pt}$: The amount of product p transported from distributor k to customer l by vehicle γ in period t , Z_{11111} = 44 , Z_{12111} = 37

$U_{ij\alpha t}$: Binary variable shows send or not the vehicle α from supplier i to manufacturer j in period t , U_{1111} = 1 , U_{2111} = 0

$U'_{jk\beta t}$: Binary variable shows send or not the vehicle β from producer j to distributor k in period t , U'_{1111} = 1

$U"_{kl\gamma t}$: Binary variable shows send or not the vehicle γ from distributor k to customer l in period t , $U"_{1111}$ = 1 , $U"_{1211}$ = 1

Variable ZZ, objective function value = 7.464642 E+7

Different scenarios of a cooperative game between supplier, manufacturer, distributor, and customer were considered and the final answer was calculated. A game between two suppliers, one manufacturer, one distributor and two customers has 16-scenarios. The total coalitions that each player is a member of is shown in Table 1.

Table 1.
The total coalitions, S= supplier, C= customer

coalition	
A	{(s1.c1)}
B	{(s2.c1)}
C	{(s1.c2)}
D	{(s2.c2)}
A.B	{(s1.c1),(s2.c1)}
A.C	{(s1.c1),(s1.c2)}
A.D	{(s1.c1),(s2.c2)}
B.C	{(s2.c1),(s1.c2)}
B.D	{(s2.c1),(s2.c2)}
C.D	{(s1.c2),(s2.c2)}
A.B.C	{(s1.c1),(s2.c1),(s1.c2)}
A.B.D	{(s2.c1),(s1.c2),(s2.c2)}
A.C.D	{(s1.c1),(s1.c2),(s2.c2)}
B.C.D	{(s2.c1),(s1.c2),(s2.c2)}
A.B.C.D	{(s1.c1),(s2.c1),(s1.c2),(s2.c2)}

To get the value of each player, the value function vector was calculated. Then Microsoft Excel estimated Shapley value of objective function optimization. The optimal values of other variables were calculated by the Shapley value method. The optimal values of the two models were compared.

V_{jpt} : The amount of production of each product p in production center j in period t , V_{111} = 78

M_{lpt} : The amount of customer l's missed order of product p in period t , M_{111} = 1

M_{lpt} : The amount of customer l's missed order of product p in period t , M_{211} = 2

R'_{kpt} : Inventory of distribution center k of product p in period t , R'_{kpt} = (all 0)

R_{jpt} : Inventory of production center j of product p in period t , R_{jpt} = (all 0)

$x_{ij\alpha st}$: The amount of part s transported from supplier i to factory j by vehicle α in period t , x_{11111} = 78 , x_{11121} = 78
$y_{jk\beta pt}$ r The amount of product p transported from factory j to distributor k by vehicle β in period t , y_{11111} = 78
$Z_{kl\gamma pt}$: The amount of product p transported from distributor k to customer l by vehicle γ in period t , Z_{11111} = 43 , Z_{12111} = 35
$U_{ij\alpha t}$: Binary variable shows send or not the vehicle α from supplier i to manufacturer j in period t , U_{1111} = 1 , U_{2111} = 0
$U'_{jk\beta t}$: Binary variable shows send or not the vehicle β from producer j to distributor k in period t , U'_{1111} = 1
$U"_{kl\gamma t}$: Binary variable shows send or not the vehicle γ from distributor k to customer l in period t , $U"_{1111}$ = 1 , $U"_{1211}$ = 1
The Shapley value of the final objective function by the game theory modeling (deficiency penalty is calculated) :
Variable ZZ, objective function value = 7.283000 E+7

Conclusion

This paper has identified the effective factors on competitiveness in the transportation network. Multiple supply chains by supplier, manufacturer, distributor, and customer structure were modeled with linear transportation programing. Game theory was used, which studies the strategic positions of players in a game. The purpose of utilizing game theory is to estimate the different ways of making a decision in a game to maximize the profit. With the Shapley value calculation, various scenarios were presented and coalition was obtained. The best coalition was chosen as the final solution. A numerical example with hypothetical values was presented in the paper. It solved by the transportation modeling issue in the Gams software. The example was re- solved by the Shapley value method cooperative game theory and the results were compared. The optimal solution obtained for the objective function by the game theory method was lower than the linear programming model, even though in the optimal solution of game theory method, deficiency penalty was added to the value of objective function. It can be concluded that game theory can achieve a more accurate and inclusive answer by considering the conditions of divergence between participants in a cooperative game. It can also be concluded that game theory can achieve a more reliable answer in a collaborative game.

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