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Modelling supply chain coordination using multidimensional auctions

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Abstract

Supply chain is a decentralized system where material, financial and information flows connect economic agents. There is much inefficiency in supply chain behavior. Recently, considerable attention of researchers is drowned to provide some incentives to adjust the relationship of supply chain agents to coordinate the supply chain, i.e., the total profit of the decentralized supply chain is equal to that achieved under a centralized system. Various mechanisms are proposed to coordinate supply chains. The use of auctions has so far been little studied. Auctions are important market mechanisms for the allocation of goods and services. The main contribution of the paper is the design of a complex trading model between layers of the supply chain. The model is based on our proposed so-called multidimensional auctions which include all auction extensions (multi-item, multi-type, multi-criteria, multi-round) into one common model and its use for supply chain coordination. We also proposed the Aspiration Level Oriented Procedure (ALOP) for solving multidimensional auctions. This approach then serves as a simulation of real auctions, where extensions suitable for reality are captured.

Keywords: Supply chain; coordination; multi-dimensional auctions

1. Introduction

Supply chain management is about matching supply and demand with inventory management. When one or more agents of the supply chain try to optimize their own profits, system performance may be hurt. Developing strategies to decrease the risk faced by the retailer is becoming more and more critical in a supply chain, especially in the global marketplace where firm-to-firm competition is being replaced by supply-chain-to-supply-chain competition. There is much inefficiency in supply chain behavior. Recent years have seen a growing interest among researchers and practitioners in the field of supply chain management. This interest was also shown at the Modeling and Simulation (M&S) conferences.

A specific problem is the coordination of supply chains. Several procedures are used in this problem. However, little work has been done on using auctions for supply chain coordination. The paper proposes a complex trading model for coordination of agents in supply chain. The model is based on, so called, multidimensional auctions. The main contribution of the paper is the design of multidimensional auctions, which include all auction extensions (multi-item, multi-type, multi-criteria, multi-round) into one common model and its use for supply chain coordination. We also proposed the Aspiration Level

Oriented Procedure (ALOP) for solving multidimensional auctions. This approach then serves as a simulation of real auctions, where extensions suitable for reality are captured.

Auctions are important market mechanisms for the allocation of goods and services. Multidimensional auctions arise by extensions of standard auction models. Multi-item auctions can place bids on combinations of items, so called combinatorial auctions. The advantage of combinatorial auctions is that the bidder can more fully express his preferences. Multi-type auction model includes forward, reverse and double auctions. Multi-criteria optimization can be helpful for detailed analysis of auctions. Multi-round, so called iterative, methods are used for analysis of combinatorial auctions and for negotiation process. Allowing bidders more fully to express preferences often leads to improved economic efficiency and greater auction profit. The multi-item model for multi-type auction is modeled with multi-criteria and solved by multi-round approach. The proposed model illustrates the possibility to formulate and solve multidimensional auctions as multi-objective programming problems. The model is based on a linear programming model and its extensions. An Iterative solution procedure is presented. The procedure is based on primal-dual algorithms.

The paper is organized as follows. Literature review of supply chain modeling and auctions is given in Section 2. Section 3 presents the supply chain coordination problem and the possibility to solve the problem. Section 4 summarizes the basics of auctions. In Section 5, a complex trading model based on multidimensional auctions is formulated. Multi-round iterative auctions as a solution approach are presented in Section 6. Finally, Section 7 provides discussions and conclusions.

2. Literature review

The field of supply chain management is often published in review books or specialized papers. There are many concepts and strategies applied in designing and managing supply chains (see Simchi-Levi et al, 1999, Harrison et al, 2003). The expanding importance of supply chain integration presents a challenge to research to focus more attention on supply chain modeling (see Snyder & Shen, 2011, Simchi-Levi et al, 2004, Tayur et al, 1999). There are a number of coordination mechanisms (Arshinder et al, 2011). Most of coordination mechanisms are based on game theory models (see Fiala, 2016) and contracts between agents of the supply chain.

Modeling and analysis of supply chains from different perspectives is also the subject of M&S conferences. Analysis and modeling of supply chains goes through the following phases: designing, managing, performance measurement, performance improvement (Majovska & Fiala, 2019). A tool-independent generalized description for sustainable supply chain design is the content of the paper (Fruhner et al, 2020). Analysis of supply chain performance is analyzed depending on demand variability (Alaswad et al, 2019). This paper studies the impact of demand variability on supply chain performance which is measured in terms of operational costs, customer satisfaction, and environmental footprint. Within supply chain design, simulation and optimization tools are used in combination to improve design scenarios from different angles. Simulation analysis is used for different phases of supply chain management. Simulation model of supply networks development Is presented (Fiala & Kuncová, 2019). The paper (Rinaldi et al, 2012) uses simulation analysis to study reorder policies for perishable food products. Sustainable supply chains optimization by mathematical modelling approach Is used (Chaabane, 2013). Supply chain analyzes are often in the presence of multiple criteria. Often the fundamental criteria are economic and ecological (Babekian et al, 2017). In this paper, the impact of carbon tax regulation on a two-stage supply chain operating under vendor managed consignment inventory partnership is studied. Other approaches are used for modeling, e.g. rule-based modeling of supply chain quality management (Cogollo-Flórez & Correa-Espinal, 2018). Principles, models, methods and algorithms for coordination in supply chain are also analyzed (Sokolov et al, 2016).

Our proposed procedure for coordinating supply chains is based on the proposed model of multidimensional auctions. Auctions are important market mechanisms for the allocation of goods and services (Klemperer, 2002, Krishna, 2002, Milgrom, 2004). In our model, we generalize standard combinatorial auctions. Combinatorial auctions (see de Vries & Vohra, 2003, Crampton et al, 2006) are those auctions in which bidders can place bids on combinations of items, so called bundles.

3. Supply chain coordination

Supply chain is a decentralized system composed from layers of potential suppliers, producers, distributors, retailers and customers etc., where agents are interconnected by material, financial and information flows. A supply chain is the collection of steps that a system takes to transform raw components into the final product. There is much inefficiency in supply chain behavior. When one or more agents of the supply chain try to optimize their own profits, system performance may be hurt.

The most important part of managing phase is the coordination of individual activities to be optimal in terms of the whole system. Supply chains are decentralized systems. A centralized system can be taken as a benchmark. The question is: How to coordinate the decentralized supply chain to be efficient as the centralized one?

We made some experiments with evaluation of different supply network structures. The supplier rarely has complete information about customer's cost structure. However, the quantity the customer will purchase and therefore supplier's profit depends on that cost structure. Somehow, the supplier will have to take this information asymmetry into account. The numbers of suppliers and customers are denoted by m, n, respectively. The symbol S_i represents i-th seller while the symbol B_j represents j-th buyer. The seller-buyer relations in supply chain can be taken as decentralized or centralized (coordinator between suppliers and customers) (see Figure 1).

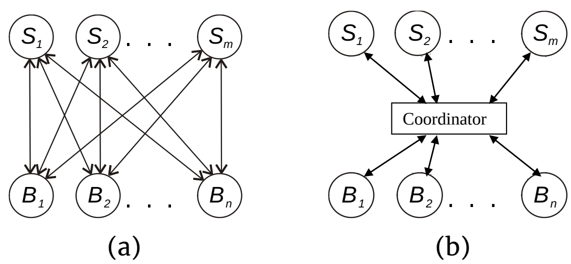

Figure 1. Decentralized (a) and centralized (b) seller-buyer relations

Most supply networks are composed of independent agents with individual preferences. It is expected that no single agent has the power to optimize the supply network. Each agent will attempt to optimize his own preference, knowing that all of the other agents will do the same. This competitive behavior does not lead the agents to choose polices that optimize overall supply chain performance due to supply chain externalities. The agents can benefit from coordination and cooperation. The typical solution is for the agents to agree to a set of transfer payments that modifies their incentives, and hence modifies their behavior. Many types of transfer payments are possible.

The problem of coordination in supply chains involves multiple agents with multiple goals. Coordination between suppliers and customers can be provided through information sharing. A seller S_i and a buyer B_j have information and analytical tools for their problem representations (see Figure 2). A coordinator helps by information sharing and by formulation of a joint problem representation (see Fiala, 2005).

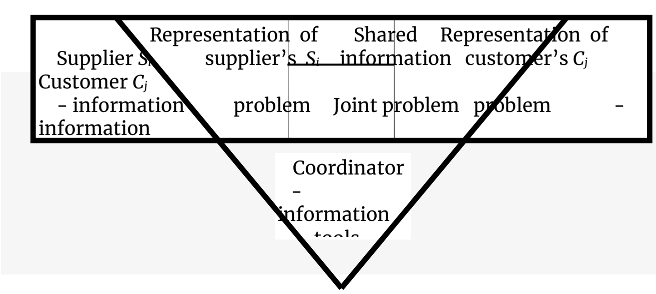

Fig. 2: Coordination through information sharing

4. Auctions

Some mechanisms for supply chain coordination are described in the literature, which are based on:

- Games.
- Contracts.
- Auctions.

However, little work has been done on using auctions for supply chain coordination. Agents submit bids reporting costs and values, and then the auction computes an allocation that maximizes the reported value and informs the agents of results. An agent pays the price it bids for the allocation it receives. If the auction receives more money than it pays out, the proceeds are distributed evenly among all consumers. Another approach based on auctions is presented in this paper.

Auctions are preferred often to other common processes because they are open, quite fair, and easy to understand by agents, and lead to economically efficient outcomes. Many modern markets are organized as auctions. Design of auctions is a multidisciplinary effort made of contributions from economics, operations research, informatics, and other disciplines. Auction theory has caught tremendous interest from both the economic side as well as the Internet industry. An auction is a competitive mechanism to allocate resources to buyers based on predefined rules. These rules define the bidding process, how the winner is determined, and the final agreement.

The auction mechanism is a process that transforms bids on allocation of objects to winners and determining the payments that must be paid by the buyer and the seller receives. An auction provides a mechanism for negotiation between buyers and sellers. Multidimensional auctions are generalizations of standard auctions. These auctions can be classified:

- Multi-item auction.
- Multi-type auction.
- Multi-criteria auction.
- Multi-round auction.

Multi-item auctions can place bids on combinations of items, so called combinatorial auctions. The advantage of combinatorial auctions is, that the bidder can more fully express his preferences. This is particular important when items are complements. The auction designer also derives value from combinatorial auctions. Allowing bidders more fully to express preferences often leads to improved economic efficiency and greater auction revenues.

There are several types of auctions (forward, reverse, and double). Forward auctions are oriented to the sale, with one seller and multiple buyers. Reverse auctions are oriented to purchase, with only one buyer and multiple sellers. Double auctions combine the two previous types and mediate an exchange between multiple sellers and multiple buyers. There is an effort to propose a general multi-type auction that covers all the types.

Multiple criteria can be defined in auctions:

- Revenue maximization - the seller should extract the highest possible price.
- Efficiency - the buyers with the highest valuation get the goods.
- Collusion possibility.

Auctions with complex bid structures are also called multi-criteria, since they address multiple attributes of the Items (price, quantity, quality, ...) in the negotiation space.

In the iterative approach, there are multiple rounds of bidding and allocation and the problem is solved in an iterative and incremental way. Iterative combinatorial auctions are attractive to bidders because they learn about their rivals' valuations through the bidding process, which could help them to adjust their own bids. There are possible combinations of the multidimensional characteristics. However, alongside their advantages, combina-torial auctions raise a host of questions and challenges.

5. Complex trading model

We propose a comprehensive trading model based on a combination of all the characteristics of multidimensional auctions.

5.1. Multi-item auctions

Many types of combinatorial auctions can be formulated as mathematical programming problems. From different types of combinatorial auctions, we present a forward auction of indivisible items with one seller and multiple buyers. Let us suppose that one seller S offers a set R of r items, j = 1, 2, ..., r, to n potential buyers $B_1, B_2, ..., B_n$.

Items are available in single units. A bid made by buyer B_i, i = 1, 2, ..., n, is defined as

$$b_i = \{C, p_i(C)\}, \text{ where} \quad (1)$$

$C \subseteq R$, is a combination of items,

$p_i(C)$, is the offered price by buyer B_i for the combination of Items C.

The objective is to maximize the revenue of the seller given the bids made by buyers. Constraints establish that no single item is allocated to more than one buyer. Binary variables are introduced for model formulation:

$x_i(C)$ is a binary variable specifying if the combination C is assigned to buyer B_i ($x_i(C) = 1$).

The forward auction can be formulated as follows

$$\sum_{i=1}^{n} \sum_{C \subseteq R} p_i(C)\, x_i(C) \to \max$$

$$\text{subject to} \quad \sum_{i=1}^{n} \sum_{C \subseteq R} x_i(C) \leqq 1, \quad \forall j \in R, \quad (2)$$

$$x_i(C) \in \{0,1\}, \ \forall\ C \subseteq R, \ \forall\, i, i = 1, 2, ..., n.$$

The objective function expresses the revenue. The constraints ensure that overlapping sets of items are never assigned. The problem (2) is called the winner determination problem.

5.2. Multi-type auctions

We present a reverse auction of indivisible items with one buyer and several sellers. This type of auction is important for supplier selection problem. Let us suppose that m potential sellers $S_1, S_2, ..., S_m$ offer a set R of r items, j = 1, 2, ..., r, to one buyer B. A bid made by seller S_h, h = 1, 2, ..., m, is defined as

$$b_h = \{C, c_h(C)\}, \text{ where}$$

$C \subseteq R$, is a combination of items,

$c_h(C)$, is the offered price by seller S_h for the combination of items C.

The objective is to minimize the cost of the buyer given the bids made by sellers. Constraints establish that the procurement provides at least set of all items.

Binary variables are introduced for model formulation:

$y_h(C)$ is a binary variable specifying if the combination C is bought from seller S_h ($y_h(C) = 1$).

The reverse auction can be formulated as follows

$$\sum_{h=1}^{m} \sum_{C \subseteq R} c_h(C)\, y_h(C) \to \min$$

$$\text{subject to} \quad \sum_{h=1}^{m} \sum_{C \subseteq R} y_h(C) \geq 1, \quad \forall j \in R, \quad (3)$$

$$y_h(C) \in \{0,1\}, \ \forall\ C \subseteq R, \ \forall\, h, h = 1, 2, ..., m.$$

The objective function expresses the cost. The constraints ensure that the procurement provides at least set of all items.

Double auctions (auctions with multiple buyers and multiple sellers) are becoming increasing popular in electronic commerce. For double auctions, the auctioneer is faced with the task of matching up a subset of the buyers with a subset of the sellers. The profit of the auctioneer (supply chain) is the difference between the prices paid by the buyers and the prices paid to the sellers. The objective is to maximize the profit of the auctioneer given the bids made by sellers and buyers. Constraints establish the same conditions as in single-sided auctions.

We present a double auction problem of indivisible items with multiple sellers and multiple buyers. Let us suppose that m potential sellers $S_1, S_2, \ldots, S_m$ offer a set R of r items, $j = 1, 2, \ldots, r$, to n potential buyers $B_1, B_2, \ldots, B_n$.

A bid made by seller S_h, $h = 1, 2, \ldots, m$, is defined as $b_h = \{C, c_h(C)\}$,
a bid made by buyer B_i, $i = 1, 2, \ldots, n$, is defined as $b_i = \{C, p_i(C)\}$, where

$C \subseteq R$, is a combination of items,

$c_h(C)$, is the offered price by seller S_h for the combination of items C,

$p_i(C)$, is the offered price by buyer B_i for the combination of items C.

Binary variables are introduced for model formulation:

$x_i(C)$ is a binary variable specifying if the combination C is assigned to buyer B_i ($x_i(C) = 1$),

$y_h(C)$ is a binary variable specifying if the combination C is bought from seller S_h ($y_h(C) = 1$).

$$\sum_{i=1}^{n} \sum_{C \subseteq R} p_i(C)\, x_i(C) - \sum_{h=1}^{m} \sum_{C \subseteq R} c_h(C)\, y_h(C) \rightarrow \max$$

$$\text{subject to} \quad \sum_{i=1}^{n} \sum_{C \subseteq R} x_i(C) \leqq \sum_{h=1}^{m} \sum_{C \subseteq R} y_h(C), \ \forall j \in R, \quad (4)$$

$$x_i(C) \in \{0,1\}, \ \forall\ C \subseteq R, \ \ \forall\, i, i = 1, 2, \ldots, n,$$

$$y_h(C) \in \{0,1\}, \ \forall\ C \subseteq R, \ \ \forall\, h, h = 1, 2, \ldots, m.$$

The objective function expresses the profit of the auctioneer (supply chain coordinator). The constraints ensure for buyers to purchase a required item and that the item must be offered by sellers.

The formulated combinatorial double auction can be transformed to a combinatorial single-sided auction. Substituting $y_h(C)$, $h = 1, 2, \ldots, m$, with $1 - x_i(C)$, $i = n+1, n+2, \ldots, n+m$, and substituting $c_h(C)$, $h = 1, 2, \ldots, m$, with $p_i(C)$, $i = n+1, n+2, \ldots, n+m$, we get a model of a combinatorial single-sided auction.

$$\sum_{i=1}^{n+m} \sum_{C \subseteq R} p_i(C)\, x_i(C) - \sum_{i=n+1}^{n+m} \sum_{C \subseteq R} p_i(C) \rightarrow \max$$

$$\text{subject to} \quad \sum_{i=1}^{n+m} \sum_{C \subseteq R} x_i(C) \leqq m, \ \ \forall\, j \in R, \quad (5)$$

$$x_i(C) \in \{0,1\}, \ \forall\ C \subseteq R, \ \ \forall\, i, i = 1, 2, \ldots, n+m.$$

The model (5) can be solved by methods for single-sided combinatorial auctions. The specific forward (2) or reverse (3) auctions can be modeled as special cases of the model (5).

5.3. Multi-criteria auctions

The combinatorial double auction problem was transformed into a combinatorial single-sided auction (5). The problem (5) is a standard form of a linear programming problem with binary variables.

Problem (5) for the simplicity of the following notation is introduced in the form

$$z(\mathbf{x}) \rightarrow \max$$
$$\mathbf{x} \in X \quad (6)$$
$$\mathbf{x} = (x_1, x_2, \ldots, x_n),\ x_i \in \{0,1\},$$

where X is a decision space, defined by restrictions. A vector $\mathbf{x}$ is a decision alternative and $z(\mathbf{x})$ represents an objective value.

Multi-criteria optimization can be helpful for detailed analysis of combinatorial auctions. The model (6) can be generalized to the model (7).

The general formulation of a multi-objective optimization problem is expressed as follows

$$\mathbf{z}(\mathbf{x}) \rightarrow \max$$
$$\mathbf{x} \in X \quad (7)$$
$$\mathbf{x} = (x_1, x_2, \ldots, x_n),\ x_i \in \{0,1\},$$

vector $\mathbf{z} = (z_1, z_2, \ldots, z_k)$ represents objective values.

The decision alternative $\mathbf{x}$ is transformed by the vector of objectives $\mathbf{z}(\mathbf{x})$ to objective $\mathbf{z} \in Z$ values, where Z is an objective space. The "max" operator means finding non-dominated solutions in this multi-objective decision problem.

The multi-objective decision problem can be formulated as a state space representation. We denote a vector of aspiration levels of the criteria as $\mathbf{y}^{(t)}$ and a vector of changes of aspiration levels as $\Delta\mathbf{y}^{(t)}$ in the round t. We search alternatives for which it holds that

$$\mathbf{z}(\mathbf{x}) \geq \mathbf{y}^{(t)}$$
$$\mathbf{x} \in X \quad (8)$$

According to heuristic information from the results of (8) the coordinator changes the aspiration levels of objectives for round t+1

$$\mathbf{y}^{(t+1)} = \mathbf{y}^{(t)} + \Delta\mathbf{y}^{(t)}. \quad (9)$$

The state space corresponds to the objective space Z, where the states are the aspiration levels of the objectives $\mathbf{y}^{(t)}$ and the operators are changes of the aspiration levels $\Delta\mathbf{y}^{(t)}$.

The start state is a vector of the initial aspiration levels and the goal state is a vector of the objective levels for the non-dominated solution.

6. Multi-round solution procedure

The paper (Fiala & Borovička, 2021) proposed a method ALOP (Aspiration Level-Oriented Procedure). We use the ALOP procedure because it naturally leads the coordinator to search for auction result proposals by changing aspiration levels of criteria. We will briefly summarize the method for solving our problem.

Supply chain coordination is a multi-objective linear programming problem, where the coordinator selects the best auction result proposal from the decision space X determined by linear constraints

$$X = \{\mathbf{x} \in R^n; \quad \mathbf{Ax} \leq \mathbf{b}, \ \mathbf{x} \in \{\mathbf{0}, \mathbf{1}\}\}$$

$$z_i = \mathbf{c}_i^T \mathbf{x}, i = 1,2, \ldots, k, \qquad (10)$$

are linear objective functions to measure characteristics of an auction proposal. Then **C** is a coefficient matrix of objectives. The decision alternative **x** is a vector of *n* variables and represents an investment portfolio.

The multi-objective linear programming problem (7) can be reformulated with aspiration levels $\mathbf{y}^{(t)}$

$$\mathbf{z}(\mathbf{x}) = \mathbf{Cx} \geq \mathbf{y}(t)$$

$$X = \{\mathbf{x} \in R^n; \quad \mathbf{Ax} \leq \mathbf{b}, \ \mathbf{x} \in \{\mathbf{0}, \mathbf{1}\}\} \qquad (11)$$

The formulation (11) corresponds to the coordinator's possibilities in finding auction result proposals by changing the aspiration levels of criteria. The problem-solving approach outlined above will be used for solving the problem (9). Searching a suitable auction proposal is a dynamic process. The coordinator states aspiration levels $\mathbf{y}^{(t)}$ for the values of auction proposal characteristics in the round *t*. Criteria requirements set by the coordinator during this process can be of varying degrees of demandingness.

Three basic possibilities for given aspiration levels $\mathbf{y}^{(t)}$ can occur. The problem (9) can be

- Feasible.
- Infeasible.
- With a unique non-dominated solution.

We will analyze these three options using a modeling approach. Vectors $\mathbf{d}^+$ and $\mathbf{d}^-$ are positive and negative deviations from the vector of aspiration levels, vectors $\mathbf{w}^+$ and $\mathbf{w}^-$ are weights of these deviations. The three possibilities can be verified by solving the following problem

$$v = \sum_{i=1}^{k} w_i^+ d_i^+ \rightarrow \quad \max$$

$$\mathbf{Cx} - \mathbf{d}^+ = \mathbf{y}(t) \qquad (12)$$

$$\mathbf{x} \in X, \quad \mathbf{d}^+ \geq \mathbf{0}$$

The value of the objective function in problem (12) can be interpreted as a utility increase *v* for the selected auction proposal.

If it holds

- $v > 0$, then the auction proposal problem is feasible and d_i^+ are proposed changes $\Delta\mathbf{y}^{(t)}$ of aspiration levels which achieve a non-dominated solution of the auction proposal problem in the next round,
- $v = 0$, then we obtain a non-dominated solution of the auction proposal problem.
- The auction proposal problem is infeasible, then we search the nearest solution to the aspiration levels by solving the goal programming problem

$$v = \sum_{i=1}^{k} \frac{1}{z_i} (\ d_i^+ + d_i^-\ ) \rightarrow \quad \min$$

$$\mathbf{Cx} - \mathbf{d}^+ + \mathbf{d}^- = \mathbf{y}(t) \qquad (13)$$

$$\mathbf{x} \in X, \quad \mathbf{d}^+ \geq \mathbf{0}, \ \mathbf{d}^- \geq \mathbf{0}$$

The solution of the problem is feasible with changes of the aspiration levels given by $\Delta\mathbf{y}^{(t)} = \mathbf{d}^+ - \mathbf{d}^-$.

The duality theory is applied for small changes of non-dominated solutions. Dual variables of objective constraints in the problem are denoted by u_i, $i = 1,2, \ldots, k$.

If It holds

$$\sum_{i=1}^{k} u_i \Delta y_i^{(t)} = 0 \qquad (14)$$

then for small changes $\Delta\mathbf{y}^{(t)}$, the value $v = 0$ is not changed and we obtain another non-dominated solution. The coordinator can make small changes of aspiration levels with respect to equation (14).

The coordinator chooses a forward direction or backtracking by determination of so-called tentative and imperative states. The imperative states contain indisputably required criteria levels. Backtracking procedure offers a possibility to return to the tentative states in a search tree and to continue in another direction while searching the state space. Results of the ALOP are the path of tentative aspiration levels and the compromise solution, which represent the auction proposal trajectory and the resulting auction result proposal for the coordinator.

7. Discussions and conclusions

Our paper follows the M&S paper (Fiala & Kuncová, 2019), where the simulation model of supply networks development was proposed. In further research, we will focus on connecting both models.

A possible flexible approach for modeling and solving multidimensional auctions is presented. This approach then serves as a simulation of real auctions, where extensions suitable for reality are captured. By entering aspirational levels in the ALOP method, we simulate the real course of auctions. But, also by simulating changes in the parameters of the supply chain, we search for a suitable coordination structure of the supply chain.

The proposed trading model has other advantages in comparisons with other approaches. Auctions are the important subject of an intensive economic research. Auctions are very popular mechanisms in practice and it is not necessary to conclude contracts between agents. Restrictions are only rules of the auction process. Auctions can be made via Internet. The approach coordinates layers of agents in supply chain, not only individual agents as by contracts. Repeating the procedure of coordination between layers of agents makes it possible to coordinate the entire supply chain. However, this procedure can be more time consuming and less accurate. In the further research, we will focus on the coordination of several layers at once.

The proposed procedure was verified on small artificial cases as well as on real situations. The analysis of the simple cases gives recommendations for more complex real problem. The combination of such models can give more complex views on auctions. Complex problems require consider multiple criteria, not just profit. Among other things, the standard combinatorial model was extended by multiple objectives. Multi objective linear programming (MOLP) problem can be used for the extended model. The problem is possible to solve e.g. by interactive methods of MOLP problems. But, we propose to solve the multi-objective problem using Aspiration Level Oriented Procedure (ALOP). The advantage of this proposed procedure is the fact that the agents need to monitor the aspiration levels of criteria only, which also corresponds to the course of real auctions.

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