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AGENT-BASED MODELING OF DYNAMIC SUPPLY CHAIN MANAGEMENT

АГЕНТНЕ МОДЕЛЮВАННЯ УПРАВЛІННЯ ДИНАМІЧНИМИ ЛАНЦЮГАМИ ПОСТАЧАННЯ

ABSTRACT. Possibilities of application of multiagent modeling in the process of management of logistic chains are considered in the article. Perspectives of this approach and its advantages are proved. The problems of dynamic supply chainsmanagement modeling are considered, the difference between agent models and system dynamics models is indicated. The features of agent-based dynamic supply chains modeling are presented. Rules for agents in the considered circumstances are formulated.

KEY WORDS: dynamic supply chains, models of system dynamics, agent models.

АНОТАЦІЯ. У статті розглянуто можливості застосування мультиагентного моделювання в процесі управління логістичними ланцюгами. Обґрунтовано перспективність такого підходу та його переваги. Розглянуто проблеми моделювання процесів управління динамічними ланцюгами постачань, зазначено різницю між агентними моделями та моделями системної динаміки. Наведено особливості моделювання динамічних ланцюгів постачань у випадку використання агентних моделей. Сформульовано правила поведінки агентів у розглянутих обставинах.

КЛЮЧОВІ СЛОВА: динамічні ланцюги постачань, моделі системної динаміки, агентні моделі.

The definition of logistics as a combination of methods and means of material flow control can be abstracted with a number of non-essential factors, in terms of management mentioned above. Thus, it is possible to compose cross-cutting logistics chains. Thisallows to formalize the description of internal processes and to make managerial decisions on this basis. These decisions are made for the main purpose of forming the initialmaterial flow that satisfies the consumers requirements.The nature of the material flow is such that on its way to consumption it passes production, warehouse, transport links. The material flow was organized and directed by various participants in the logistics process. The methodological basis of the through-flow management of the material flow is the system approach, the principle of implementation of which in the concept of logistics is put in first place. For the traditional approach to managing, each link in the logistics chain has its own management system that is geared towards its own goals and performance criteria.Output material flow of each previous link of the logistic chain, formed under the influence of the management system of this linkis the input for the next link,taking into account its goals and criteria. The resultant material flow of the entire logistical chain is the output stream of the last link. Its parameters are determined as a result of independent control effects, carried out in each of the links of the logistics chain sequentially. Therefore, from the point of view of general management objectives, they are spontaneous [1, 5, 6].

In the logistic approach, control actions are applied from the side of a unified logistics management system to a new control object — the through material flow. These control actions are formed on the basis of general objectives and criteria of efficiency of the investigated logistic chain, so that the parameters of the initial material flow are predictable completely.

The operating of real logistic systems is characterized by the presence of complex stochastic connections both within these systems, and their relations with the environment. Under these conditions, the adoption of private decisions, without taking into account the common goals of the system operating and the requirements imposed on it, may prove to be inadequate, and possibly false. A system approach does not exist in the form of a strict methodological concept. It is a kind of set of cognitive principles, the observance of which allows certain orientation of specific research. When forming logistics systems, the following principles of a systematic approach must be taken into account: the principle of successive advancement in the stages of system creation.Compliance with this principle means that the system must in first be explored at the macro level, that is, the relationship with the environment, and at the micro level, i.e. within its structure. It based on the principle of information harmonization, reliability, resource and other characteristics of projected systems, as well as the principle of the absence of conflicts between the objectives of individual subsystems and the goals of the whole system.

A characteristic feature of the formation of logistical control systems is that such a system should first be analyzed in order to establish relationships with the environment, and then the interconnections within the molded system should be established.

Logistic control systems, like any system in reality, can be at different stages of development and vary in the degree of completeness of the coverage of various components of production and marketing. For application of logistic control systems, four levels of development or four levels of coverage of the production-sales systemcomponentsare inherent.

For logistic systems, the first degree of completeness of components coverage is characterized by the performance of the functions of warehousing products ready for shipment, and its transportation to consumers. Such a logistics system ensures damping at the exit by correct and timely response to daily peaks and fluctuations in consumer applications and unforeseen delays in delivering products in the process of satisfying these applications. For logistic systems of the second degree of component coverage characteristic completeness the competenceis was limited by distribution of their own productionoutputs. Such systems, along with the coverage of the system for the transportation of products to consumers and warehouses ready to ship products, which is inherent in systems of the first degree of completeness, also covers the in-factory warehouses of finished products.The function of such systems is the processing of orders. For logistic systems of the third degree of component coverage completeness, it is characteristic the extension of their competence additionally (in comparison with systems of the second degree of thecomponentscoverage completeness) on the input depots, the delivery system of raw materials, the scope of procurement and supply, as well as on the movement materials during the production process. In accordance with this expanded competence, such systems, in addition to the ones discussed above, fulfill the functions of managing the procurement of raw materials and components, delivery of raw materials and components, inventory control of raw materials and components, as well as the level of work in progress. The work of a logistics system of this level is usually carried out using the current annual plan. Logistic management of third-level systems consists of generating preventive effects, and is not limited to adequate response to spontaneous deviations.

Logistic systems of the fourth degree of component coverage completeness extend their competence to all elements and stages of the production and marketing process, including the planning and management of their own production. This makes it possible to combine the results of marketing research with operations planning, production, supply and finance. Such logistic management uses the principle of integration and is based on the already mentioned idea of economic compromises. The work of a logistics system of this level is usually carried out using long-term plans (compiled for a period of more than one year). The feasibility of introducing a specific production and distribution system of logistic management in each individual case requires a special consideration [2, 4].

Let’s consider the application of agent modeling in the field of dynamic supply chainsmanagement. The basis of this approach to modeling are agent-oriented models (AOM). AOM is a special class of computable models based on the individual behavior of agents and created for computer simulations.

Such computer simulations are closely interconnected with the following concepts: complex systems, the Monte Carlo method, computational sociology, systems with many agents and evolutionary programming, etc.

At the core of agent-oriented models are three basic ideas:

1) object orientation;

2) the ability of agents to study (or their evolution);

3) the complexity of the calculations.

A dominant methodological approach is one, which calculates the equilibrium or pseudo-equilibrium of a system containing a pluralityof agents. In this case, the model itself, using simple rules of conduct, can produce very interesting results. AOMs consist of agents that dynamically interact according to certain rules. The environment in which they interact can be complex enough.

The main properties of agents in AOM are:

1) intelligence. At the same time, this property should be moderate so that agents can not know anything beyond the rules of the game;

2) the existence of a vital purpose;

3) location in time and space [3].

It means a certain "place of existence", which can be represented both in the form of grid, and in the form of a much more complicated structure. Sometimes the result of the interaction of agents in the "place of existence" — the balance, sometimes — the continuous process of evolution, and sometimes — an infinite loop without a specific solution.

It is believed that AOM complement traditional analytical methods. The latter allow us to characterize the equilibrium of the system, and AOM — to investigate the possibility of obtaining such a state. AOMs can explain the cause of such phenomena as: terrorist organizations, wars, stock market collapse, etc. Ideally, the AOM can help to identify the critical moments of time, after which the extraordinary consequences will be irreversible. AOM can help in studying the influence of individual behavior of agents on the evolution of the entire system [1].

Unlike system dynamics or discrete-event models, in the framework of agent-oriented modeling, there is no such place where the behavior (dynamics) of the system as a whole is determined centrally. Instead, the analyst defines behavior at the individual level, and the global behavior emerges as a result of the activity of many (tens, hundreds, thousands, millions) agents, each of which follows its own rules, lives in the general environment and interacts with the environment and other agents. Therefore AOM is still called simulation from the bottom to the top.

The authors [5, 6] note the characteristic features in the construction of agent models. In addition to the standard tasks of constructing a model, practical AOM requires the following steps:

— *definition of agents and theoretical basis for the agentsbehavior;*

— *definition of the relationship between agents and the theoretical foundations of such relationships;*

— *search for a AOMplatform and develop a strategy for AOM model;*

— *obtaining the necessary data for agents;*

— *validation (validation phase) of the agent behavior model (in addition to the model as a whole);*

— *the launch of the model and the analysis of the source data in terms of the relationship between the behavior of agents at the micro level and the behavior of the system as a whole.*

Defining agents with the exact task of their behavior and interaction with other agents is the basis for developing reliable agent models. Agents are those who usually make decisions on the system (the decision makingperson — DMP). And they may be:

– traditional DMP;

– managers;

– non-traditional DMP (complex computer systems with complex behavior);

– groups (if it is dictated by the objectives of agent modeling).

Once the agents are identified, the next main task is to determine the behavior of agents. Here the following can be recommended:

- find the theoretical basis for the behavior of agents. For example, you can start with a normative model and use this model as a starting point for developing a simple and evident heuristic behavior model;
- a behavioral model can also be started with if there is a suitable behavioral theory and the results of its application look adequate. For

example, there is a large number of theories for modeling buyer behavior based on empirical knowledge;

- when the behavior of individuals (people) is used as the basis for agent models of existing or hypothetical systems, useful techniques can be borrowed from engineering knowledge and general simulation.

The general AOM combines an agent modeling paradigm with organizational theory ideas to define a managed model, and which consists entirely of people who play roles, much like a game, but much more structured. General simulation is useful to use at the initial stage of development of the agent model. Using the correct structure, instructions, and discipline, people in the general AOM can reveal much more information about the behavior of agents, namely:

— How much information can people handle at a given time for decision making?

— What factors and signs people consider most important for decision-making?

— How does the past experience of people influence the process of decision-making?

— Which strategies from those formulated by people are the most effective?

A common agent modeling can be used to improve the understanding and validation of the functioning of agent models to determine if these models are plausible, to demonstrate the concepts of agent modeling to all stakeholders and to test the ideas of the behavior of agents in non-standard situations.

Let’s consider the technology of agent-oriented modeling of the supply chain. The supply chain consists of four parts: manufacturing, distributors, wholesalers and retailers that respond to end-user inquiries.

To simplify the model, the following conditions are proposed:

— there is only one product

— there is no transformation of goods,

— it is also unacceptable and not necessary to assemble different materials into the final product.

The flows of goods and information are reflected in the form of applications between different stages (agents), the model includes transfers (money), but there are no payment flows, as well as negotiations and financial calculations. It should be noted that these aspects of the behavior of supply chain agents can easily be subsequently included in the final agent version of the model.

Agents in the supply chains are consumers, retailers, wholesalers, distributors, and factories (see fig. 1).

In each period of time, agents of supply chains perform actions, guided by the following rules of their behavior:

1) the consumer applies for a retailer;

2) the retailer satisfies the application immediately from the relevant stocks, if there is enough stock in the warehouse (if the stocks have expired, then the consumer’s application is placed in default and is executed on condition of the warehouse replenishment);

3) the retailer receives the next consignment from the wholesaler in response to the previous application. The retailer decides how much of the cargo to order a wholesaler, based on the "rule of the applications." It also evaluates future consumer orders, using the rules of "forecast requirements (applications)." Then the retailer orders the goods from the wholesaler to cover the expected requirements and any shortage of stocks and goals that are explicitly stated;

4) similarly, each wholesaler receives goods from the manufacturer and submits applications to distributors, based on the requests of retailers. This process continues further up the chain to the manufacturer, who decides how much productsto produce.

The purpose of the agents in this simulation is to manage their own inventories in order to minimize their cost through rational decisions based on how much the product should be ordered at each time period.

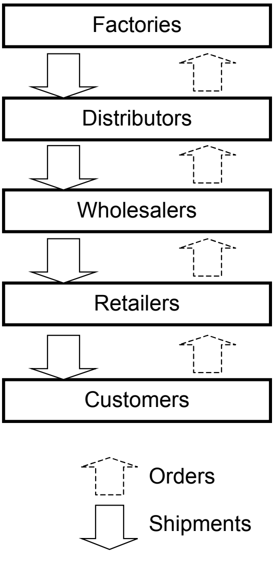

Fig. 1. Typical net of supply chains and agents
(orders — orders; shipments — goods (goods))

When stocks are virtually insignificant and there is a danger of their devastation, agents order more; when there are too many stocks and the agents bear high costs for storing these stocks, they order less goods. Each agent is responsible for storing the goods in stock. Agents also bear overhead when they receive an application (order) and can not perform it immediately due to lack of inventory in stock. Each agent makes a choice between too large stock, which increases storage costs, and too little inventory in stock, which increases the risk of ending goods and he will have to bear overhead.

In this example, supply chain agents have access to local information only. None of the agents sees the entire supply chain or can not optimize the whole system. Adaptive decision-making rules use only local information for decision-makers.

To construct the considered agent model, formalisms of any object-oriented language can be used. As noted earlier, the supply chain model includes consumer agents, retailers, wholesalers, distributors, and manufacturers. Any component of a model can either be an agent or an object; individual objects in the simulation are timer and set of output reports. Agents of distributors, retailers and wholesalers can be grouped into one group called "MiddleAgents" (medium or intermediate agents), since they all have a similar structure in terms of a set of attributes and techniques.

Each class of agents is fed through a set of attributes and techniques (operations) that can be performed over classes. For example, the manufacturer’s agent can be represented by the following attributes: agent name; inventory level; desired level of stocks; quantity of goods in the system of sales; the amount of inventory received, shipped and ordered; various parameters for making decisions, etc.

During the process of modeling the impact on the behavior of agents and environmental factors (nonagents)should be taken into account. For example, the variable magnitude of the the external environment impact can be indicators of salaries and their dependence on the geographical location.

Also, when simulating, it is necessary to consider also that the attributes of agents can be changed as a result of interagency interactions or interaction of agents with the external environment. For example, within the supply chain model, inventory levels are an attribute of each of the agents. This level changes are a result of receipt of orders or shipment of goods.

Thus, in the article the problems of management processes modeling in dynamic supply chains are considered, the difference

between agent models and system dynamics models is indicated. The features of agent-based dynamic supply chainsmodeling are presented, and rules of agentsbehavior under considered conditions formulated.

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