An agent-based computational model for strategic investment decision processes

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Abstract: In this paper we create a scenario that occurs in the evolution of some companies and is considered to improve the company’s position by means of competitiveness and organizational performance. The scenario represents an approach to solving the transportation problems within a company, especially when it comes to grouping and organizing shipment in order to reduce costs and be more competitive than other active agents on the market. Customer need is an extremely important factor and its fulfillment cannot be delayed, but it is also hard to satisfy when the economy handles random micro behaviors among consumers with an increasing impact on the course of the organization. Therefore, companies often have to synchronize the need for expansion with the necessary allocation of resources and the organizational culture; it is our purpose to analyze through an agent-based computational model, whether this scenario in the given circumstances is worth being developed or not.

Key-Words: Agent-based model, computational economics, agent behavior, investment decision, planning algorithms, active learning

1 Introduction

The applicability of agents and agent-based models occur in various domains like economy, industry, commerce, information technology, but what motivates this paper is the agent-based economy, which exclusively studies new models able to solve the actual common economic issues.

Whether we refer to resource management, investment policies, production, distribution or sales, none of these processes exists without the entities behind it. Each entity involved in a major organizational process will be known as an agent.

The group of economic entities that behave and interact according to their internal objectives and constraints is a dynamic and complex system in which every interaction is being studied and modeled [10].

The actual surveys on agent-based models are focused on finding a pattern in the agent’s behavior, which shall stand as a benchmark for further simulation processes. Of course, this method has been used in many traditional approaches regarding economic modeling; however, it must be mentioned that the specific rationality and general equilibrium concept used as starting points in the traditional approaches, are being replaced by the active learning of agents.

Agent-based models have a significant impact not only on the computable aspect of their behavior, but on the interactions among agents themselves, excluding actions that are unrealizable by a computer [9].

The market economy based upon a free price system is considered as a complex and adaptable system which reunites a large number of adaptive agents that establish local connections [6]. In an agent-based model, agents are being viewed through a computational approach that allows interactions to be simulated on a computer.

2 Agent-based modeling

The dynamics of the business environment enforces the need for new modeling techniques and powerful simulations of the flow circuit, and the organizational and market behaviors.

Agent-based modeling is a powerful simulation modeling technique that has seen a number of applications in the last few years, including applications on real-world business problems. Similarly, agent-based programming adds abstraction entities, i.e., agents that have an independent execution thread and pro-activity towards object-oriented paradigm. Thus, compared
to an object, an agent is able to act in a goal-directed fashion (e.g., by interacting with other agents, reading sensors, or sending commands to effectors) rather than only passively react to procedure calls [1].

The traditional approaches in economic modeling, especially based upon general equilibrium, rational expectations, computational econometrics and statistics, or other computational tools do not constrain the results of an agent-based simulation.

2.1 Agent Design

The core of the agent-based modeling concept is represented by the active learning of agents, which has led to various learning algorithms that constantly needed to be optimized by objective formulas [6].

Before designing an agent, first we must identify and specify its behavior and appropriate interactions. Agents are most often designed in order to interact with other agents within a network, maintaining their autonomy during the entire simulation process.

Additionally, agents are often designed with evolutionary algorithms, which allow the agents to learn about their environment and formulate unique sets of decision rules [1].

Fig. 1 – The basic processes of the classic supply chain

One agent’s behavior is based upon a set of rules, patterns and information that uniquely identifies them in the projected environment.

It is considered that the constraints of the environment in which agents interact and behave, determine the nature of the interactions in terms of spatiality.

The basic hypothesis relies on the fact that agents belonging to regional environments are more likely to interact and influence one another than the distant ones [6].

In this paper, a particular form of a supply chain model is presented, once which does not consist of the classic diagram (Fig. 1) but of its start and end points, meaning the supplier and the final consumer. The economic concern regards not only to the transformation of the supply chain, but also to the economic sustainability behind it.

2.2 Agent-based modeling benefits

The agent-based modeling techniques distinguish themselves from among traditional approaches mostly because of the lack of abstracting that we usually find in other concepts [4]. The agents, the interactions among them and their decisions are being carefully analyzed and are considered to be the benchmark for future assumptions.

Concrete examples may refer to the behavior of one company’s customers and the patterns they phrase in order to get a density equation, whose aggregate properties can be easily studied by the agent-based models.

Knowing the actual shopping basket of a customer makes it possible to create a virtual agent with that shopping basket rather than a density of people with a synthetic shopping basket computed from averaging shopping data [1].

The specialized literature brings out flaws in traditional statistics and econometrics methods of providing predictive models, as it is considered that these models do not allow the analyst to explore more underlying relationships. Econometric methods usually estimate empirical relationships according to an observed data range, but such estimates often break down when extrapolating outside of that range [10].

On the contrary, agent-based models allow the analyst to explore and provide predictive models, even in the situation when interactions among agents cannot be explicitly handled by the traditional approaches. When adding a high level of heterogeneity of data, the constraints of the classic assumptions determine an inflexibility that has no positive effects upon the modeling.

Decision making process represent a concept that is rarely not the major actor for every algorithm, method, technique, research or any economic topic.
within scientists. The need of prospecting future actions or consequences is fundamental to any level of decision, whether is pure experimental or it actually relies on economic realities.

Therefore, a data modeling is not only vital as a response in the present moment, but as a time perspective as well; it has no significant meaning to the analyst if it is not studied over time.

The time dimension represents another benefit of agent-based models, which combined with active learning, lead to serving multiple purposes [11].

![Fig. 2 – Business processes and agent views of an agent-based model (Source adaptation: [7])](image)

The quantification of variables that influence the equilibrium of one system is not being established as in the traditional approaches, because the agent-based models do not assume that an economic system is initially in some sort of equilibrium state [1]. Nevertheless, the major considerations made more upon activities among agents and not strictly upon the business processes that these are involved in, depart once again from the abstract approach of the traditional techniques (Fig. 2).

### 3 Problem Formulation

In this paper we present one of the main functionalities of every organization that handles typical logistic problems. The correlation between the point of origin and the point of destination in order to meet the requirements of customers is one common definition of logistics itself and an aspect that is constantly in need of optimization [10].

To be more specific; due to the complexity of the domain, the specific field that draws our interest in this paper is the physical distribution process.

The distribution of goods in any company refers to that set of activities that are concerned with the efficient movement (in terms of time and freight) of finished goods from the end of the production process to the consumer.

One random good obtained at the end of the production operation, which is being distributed to its customer, involves a developed relationship with the suppliers or resellers that represent the main components of the chain distribution.

The distribution channels are not only a listing of organizations that are connected through different kind of flows, but complex behavioral systems as well [3]. Therefore, it occurs to us as a legitimate consideration that the company, the customers (which of course can be other firms) and the process of the distribution itself are actually agents acting in an environment ready to be studied and simulated by an agent-based model.

The intermediates in the distribution chain usually have a great impact on the price policies, due to the fact that they link the big volume of the produced items with the small amount of the bought items. It is clear that producers are usually interested in selling a limited range of products but in large quantities, while the final consumers do exactly the opposite. The link between the two specific behaviors is accomplished by the resellers or the intermediates, which combine these two and act as leverage on the demand-supply concept.

The presence of intermediates on the distribution chain significantly improves time and cost strategies that suppliers always have to take in consideration, especially when facing boundaries related to time and space between the origin point of the good and the final consumer. Thus, there are suppliers that do not adopt the classic distribution chain and choose to include the shipping and distribution management in their organizational behavior.

When we face a situation in which a company decides to play the second role as an intermediate agent, it is wise to gather information about the future course of any decision of this kind.

Agent-based Modeling and Simulation promises to have far-reaching effects on the way that businesses use computers to support decision-making and researchers use electronic laboratories to support their research [5].

The current surveys regarding new concepts of modeling logistic processes actually mention the effect of logistics upon production, not in terms of significance, but in terms of hierarchy and staging.

The concern of the model presented in this paper, regards the activity of a supplier that decides to develop regional retail marketing for its end customers. The decision itself is being analyzed, as long as its economic sustainability, but rather the way the company is going to behave efficiently in
the process of combining the two different activities and act not only as a producer, but as an intermediate as well.

Among the basic modes of transportation, we refer to the road transportation only, any other differences between this and other options being related mainly to costs and time.

The company will have to deal with a change of perception regarding the sales strategies so far; it will have to adjust small demanded amounts with a various range of supply, in order to maintain competitively on the market. It is clear that these aspects force the company to reanalyze the desired strategy of becoming supplier to the end customer, but without a well documented investment decision, financial resources will not be allocated to any external process.

The alternative approaches for traffic management: evolutionary algorithms, knowledge-based systems, neural networks, fuzzy systems, and for transport scheduling: classical mathematical and/or methods, i.e., mainly centralized approaches [2].

4 Building the agent-based model

Information and attributes need to be gathered so that the modeler designs classes of agents and agents with functionalities such as interactivity and the execution of further simulations. The agent behavioral pattern turns it into a computable entity, instanced and simulated on the computer., that is being analyzed over different time periods and examined periodically.

We therefore require substantial understanding about the underlying information, decisions, and transactions that are pertinent to real-world economic participants [10].

The company that now acts as a double player, once as a producer and secondly as a distributor, has to handle the strategic issue of controlling functionalities within the operational decision making.

Specific concerns regarding the location of distribution centers, grouping partial shipments, assembling purchasing orders by shipment address and offering an estimated delivery time to customers are activities that involve not only scheduling but a thoroughly staging process as well.

But before starting to design any model, we must take in consideration the process of production planning and nevertheless financial planning.

The software agents that take place and interact with other agents in the environment need to engage in cooperative and/or competitive tasks to effectively achieve their design objectives [2].

Road transports involve the allocation transport task to vehicles and the agents who play this role might be the company, the truck/vehicle or the customer.

In the classic supply chain model (Fig. 1), the supply chain agents consist of suppliers, intermediate agents and customer agents. The term of intermediate agents gather distributors, wholesalers and retailer agents which can therefore be considered as a class of agents.

Each class of agents is characterized by some features such as attributes or methods that apply to every agent member.

Everything in the simulation is either an agent or an object; other objects include the clock and the set of output reports [3].

Thus, this paper focuses on the possibility that a supply chain starts directly at the production line by no further bifurcations, and ends directly to the customers (Fig. 3). Modern supply chains have multiple levels, and it is often inefficient to manage each level independently. Alternative methods to agent technology in road transport are classical mathematical methods, operations research, and centralized approaches [2].

Various companies have installed sophisticated supply chain planning systems to replace separate layers of independent decisions.

Firms address their objectives over a multiple-period time horizon by forecasting demand for their products. From these forecasts, they devise business plans, which specify outlays off fixed capital (i.e.,
fixed-capital investments), and planned levels of payroll, purchases, and revenues [5].

Once we have established the agents, the classes of agents and the interaction within them (Fig. 4), it is time to visually represent a more specific diagram that shall support the modeling of system structure.

![Fig. 4 – Particular business functionalities](image)

The main issue that the supplier company must handle in our scenario is represented by the fragmented purchase orders placed by a large number of customers, characterized by a high level of heterogeneity. Therefore, clients demand small amounts of different goods, with different kind of packaging and features, within a discontinuous range of shipping addresses.

![Fig. 5 - Logistics chain UML diagram](image)

Models provide the abstraction of a system or a projection, mainly within the benefits of an aggregated perspective upon objects and solutions that are significantly relevant to further analyzes [9].

We must now mention that agent-based models have a lot of impact on those situations in which the processes are simplified (Fig. 4), precisely because the activities related on these are extremely complex and dynamic.

The UML representation is at a high level of abstraction, independent of the model’s implementation in the particular object-oriented programming language used [5].

![Fig. 6 – The purchase orders module of the application](image)

Therefore, our choice is that our agent-based model should firstly rely on a unified modeling language (UML) diagram as presented in Fig. 5.

![Fig. 7 – The payment module of the application](image)

Our agent-based model has materialized into an application with several modules, as in Fig. 4. Thus, we present the two synchronized activities that have been analyzed and modeled in this paper: the purchase orders management (Fig. 6) and the
purchase payments management (Fig. 7), regarded as supply chain financial flows. Most companies require significant amounts of Working Capital to deal with variable and somewhat unpredictable financial inflows and outflows.

5 Conclusion
The agent-based computational economics modeler specifies the initial state of an economic system by specifying each agent’s initial data and behavioral methods and the degree of accessibility of these data and methods to other agents [11].

The field of production management and logistics is currently undergoing major changes, due to increasing structural and dynamic complexity of the production system. Also, the production system itself is often regarded as a sub-system of a logistics network [8].

Due to the fact that there is not an algorithm of any kind that could be exactly applied to any two types of businesses, it is obvious that we cannot refer either to a best approach in creating an agent-based model. However, there are various patterns to take into consideration when building an agent-based model, such as mechanisms designed to monitor the inputs from the environment, their history and previous aspects or the future outputs.

The financial flow in a typical supply chain includes thousands of invoices and payments in a given year [7].

The supply chain financial flow is at a critical threshold of evolution. Current trends in supply chain and financial flow management clearly favor the use of automated payment solutions.

Most large-scale agent-based modeling toolkits that provide basic agent functionality are based on the object oriented paradigm. Agent-based simulation is not the same as object-oriented simulation, but the object-oriented modeling paradigm is a useful basis for agent modeling, since an agent can be considered a self-directed object with the capability to autonomously choose actions based on the agent’s situation [5].

The agent-based approach developed in this paper has found its sustainability in the ability to distribute control and dealing with fractioned or noisy data sets. The customer satisfaction is not only related to the nature of the goods, but also related to their physical distribution from the production line to households.

References: