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# THE CONCEPT OF SIMULATION MODEL
# TO STUDY CONSUMER BEHAVIOR

### Summary

The aim of the article was to present multi-agent based simulation (MABS) model to study consumer behavior. There was described the essence of multi-agent based simulation and multi-agent simulation modeling procedure. This procedure became the basis of theoretical assumptions for building simulation model of consumer behavior on the market of electrical appliances.

**Keywords:** consumer behavior, decision-making process, multi-agent based simulation (MABS), simulation model

## Introduction

In the contemporary, multidimensional, dynamic and competitive marketing environment consumers are more demanding and aware of possibilities given by supply. Their tastes and preferences are changing very quickly, and the pace of these changes is connected with the number of products appearing on the market, their constant technological and functional improvement as well as a fast transfer of consumption patterns. These factors indicate necessity for constant consumer behavior research in order to identify, understand, forecast and possibly shape it. Consumer behavior research requires using appropriate methods.

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One of the methods which allows conducting research concerning predicting consumer behavior is multi-agent based simulation. An important stage in application of this method is building a simulation model. The aim of the article is to present the concept of multi-agent simulation model to study consumer behavior. The article presents the essence of multi-agent simulation and multi-agent simulation modeling procedure, on the basis of which there were elaborated theoretical assumptions for building simulation model of consumer behavior on the electrical appliances market.

## 1. Consumer behavior research

Consumer behavior research allow us to better understand and predict not only factors connected with purchase but also motives and frequency of doing shopping. Currently, one of the basic assumptions in consumer behavior research is the view that people often buy consumer goods not because of their basic function but because of their subjectively perceived value (Stávková et al. 2008). It does not mean that the basic function is not important, but it means that contemporary role of consumer goods is not confined to their usefulness (Solomon 2004). What is more, consumer often do not judge products on the basis of their basic usefulness but on the basis of certain particular product features, which are a set of immaterial factors bringing a consumer expected profits – image, counseling, after sale service and other (Foret, Procházka 2007). There are many factors that influence consumer decision making process, and they are classified in literature
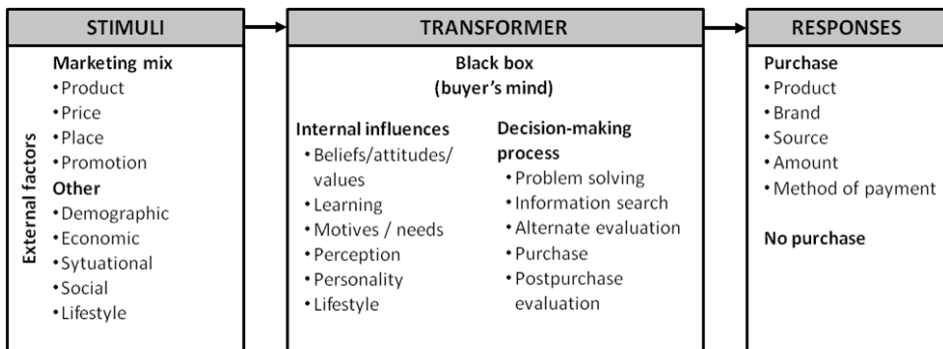


Figure 1. Consumer black box model

Source: own elaboration based on: Keegan et al. (1992, p. 193); Kotler et al. (2002).

in many different ways. The complexity of these factors is very well illustrated by consumer behavior model called the black box model (Figure 1).

Currently, marketing actions are focused on searching for ways of providing clients with satisfying products and services as well as on methods of maintaining their interest in order to make profit, enhance the company's competitiveness and guarantee the desired market share. Due to the fact that consumer behavior is a complex system there is a problem of discovering rules which govern decision making. Contemporarily, the researchers are trying to find the answer to the following questions:

– How consumers (households) take decisions concerning purchase?
– How is it possible to check their behavior under different conditions and in terms of different scenarios?
– How to eliminate consequences of mistaken decisions concerning marketing plans?
– How is it possible to analyze various versions of marketing plans without any cost?

To find the answer to the questions above researchers apply many methods of consumer behavior modeling. They are, among others, techniques based on fuzzy logic, neural nets, decisive trees, genetic algorithms. The analysis of the applied approaches and methods allows constatation that frequently they do not take many factors into consideration or are not precise enough. Hence, the proposition of applying multi-agent based simulation in consumer behavior research. The concept presented by authors in the present article was elaborated on the basis of modeling and multi-agent based simulation. Because of that this method will be described in the subsequent point.

## 2. The essence of multi-agent based simulation

Agent-based modeling and simulation (ABMS) is a computational technique widely used for studying complex systems, such as biological systems, ecosystems, financial, political and economical ones. ABMS may be used for analyzing how the processes on microeconomic level influence results on macroeconomic level (Siebers, Aickelin 2007, p. 5).

In other words, agent-based modeling and simulation is a new modeling paradigm and it is one of the most interesting practical achievements in modeling since implementing data bases. ABMS may have great influence on the way in

which companies use computers for supporting decision making process as well as on the way in which researchers apply IT solutions to support their research (Macal, North 2006).

ABMS includes creating artificial agents designed to imitate attributes and behaviors of their real equivalents. From a practical point of view it is assumed in modeling that agents have certain features (Macal, North 2006):

- an agent is an identifiable, autonomous unit equipped with a set of features and rules governing its behavior and decision making ability; agents are independent; the requirement of autonomy suggests that each agent has boundaries and, because of it, it is possible to ascertain if something is or is not part of an agent or common feature,
- an agent is placed in a particular environment in which it makes contact with other agents; agents have defined protocols of interaction with other agents, for example: communication, ability to react on changes in environment; agents are able to recognize and distinguish other agents' features,
- the agent's actions can be directed at achieving a particular goal,
- an agent is autonomous and independent, it can function independently in its environment and in contacts with other agents, at least in certain defined situations,
- an agent is flexible, it has got the ability to learn and adept behavior on the basis of its experience; it requires a certain form of memory.

Agents can realize certain behaviors appropriate for the system which they represent, for example by producing, consuming or selling. The occurrence of repetitive, competitive interactions between agents is a basic feature of agent based modeling, which is based on using computers computational power for studying system dynamics, which is out of purely mathematical methods reach (Axelrod 1997; Epstein, Axtell 1995). These assumptions particularly predestine multi-agent based simulation for applying in consumer behavior research, as it can show how out of many agents actions identifying individual and/or organizational consumers arise aggregated marketing phenomena.

In the simplest arrangement, multi-agent model consists of agents system and relations between them. It has to be noticed that even a simple model can show complex behavior patterns (Reynolds 1987) and provide us with valuable information on real system dynamics which it models. In ABM procedure an agent is formalized as a unit that takes decisions on the basis of its own aims,

possessed information concerning environment and its expectations towards future. Agents aims, information and expectations are influenced by interactions with other agents (Figure 2). Usually, agents have adaptive abilities, which means that they can change their decisive strategies, and as a result their behavior.
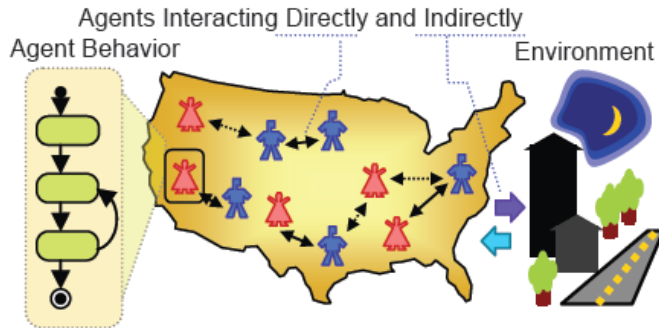


Figure 2. Agent-based model structure
Source: own elaboration on the basis of: Garifullin et al. (2007).

As it results from the considerations above, the main benefits of using ABM and its predominance over other modeling methods are the following (Bonabeau 2002):

– ABM captures emergent phenomena: because ABM generates emergent phenomena from the bottom up (result from the interactions of individual entities), it raises the issue of what constitutes an explanation of such a phenomenon; the broader agenda of the ABM community is to advocate a new way of approaching social phenomena, not from a traditional modeling perspective but from the perspective of redefining the scientific process entirely,

– ABM provides a natural description of a system; in many cases, ABM is most natural for describing and simulating a system composed of ''behavioral'' entities; whether one is attempting to describe a traffic jam, the stock market, voters, or how an organization works, ABM makes the model seem closer to reality; for example, it is more natural to describe how shoppers move in a supermarket than to come up with the equations that govern the dynamics of the density of shoppers; because the density

equations result from the behavior of shoppers, the ABM approach will also enable the user to study aggregate properties,

– ABM is flexible: the flexibility of ABM can be observed along multiple dimensions; for example, it is easy to add more agents to an agent-based model; ABM also provides a natural framework for tuning the complexity of the agents: behavior, degree of rationality, ability to learn and evolve, and rules of interactions.

Depend all these benefits we can say the ABS is the best approach applied to simulate human behavior in social science and marketing researches such as consumer behavior on market. It is a powerful tool in this area because (Rand, Rust 2011):

– it has allowed researchers to include consumer-level behavior models of richer fidelity that have been used to examine the robustness of various marketing strategies,

– the movement patterns and behavioral decisions of each and every consumer can be modeled separately,

– potential insights that could be gained in this area could relate to the examination of the interconnected role of service points and queuing,

– the ability to examine hundreds of thousands of retail location layouts in a small amount of time,

– the discovery of unknown interactions between purchase decisions and consumer movement.

Using multi agent based simulation means obeying a certain defined modeling procedure (Figure 3), which begins with formulating the problem and defining the aim. The next step is to define simulation environment in the researched area (most importantly the agents, space and environment) and to define system boundaries. Another step of the procedure is connected with gathering input data for the model. For the experimenter the part of research procedure which concerns defining methods and information gathering (measuring) techniques is the most important because a wrong method choice can make reaching the research goals impossible. In the literature and practice there are three basic kinds of measurements: secondary measurement based on secondary sources, primary survey measurement and measurement in a form of experiment – both based on primary sources (a broad review of gathering data from secondary and primary sources is included in the following publications: Kaczmarczyk 2003; Kędzior et al. 2005; Pfaff 2010).
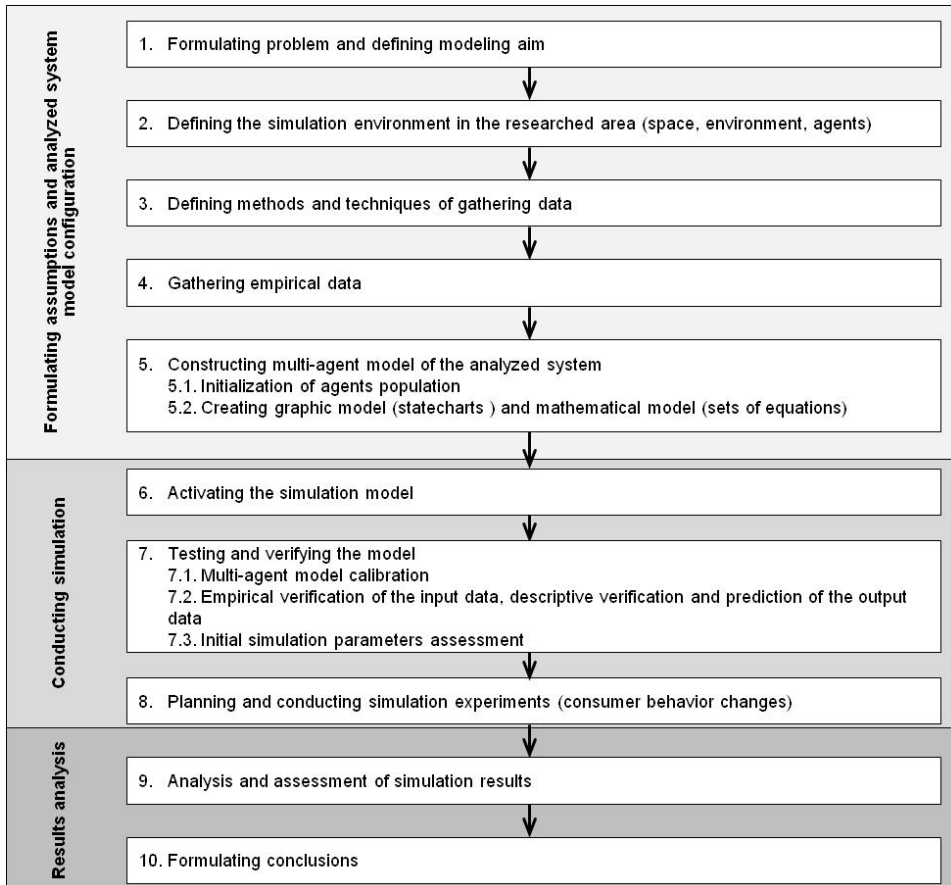
Figure 3. Multiagent modeling procedure
Source: own elaboration.

On the basis of the gained data it is possible to start constructing the multi-agent model of the analyzed system. In the consumer behavior research in which the multi-agent approach is applied, the empirical data concerning particular consumers and their reciprocal interactions characteristics are used to formulate rules of acting in simulated environment agents' behavior. The starting point in conducting multi-agent simulations is initialization of a certain population of agents. They can represent economic entities and other social phenomena. Initialization means defining agents attributes values (their internal states), rules of behavior (also rules of possible modifications of behavior during simulation

i.e. learning) and rules of communication between them. Unfortunately, the data gained from surveys can not deliver direct information possible to apply in the agents creation process. Usually, in such situation, the statistical analysis of row empirical data is conducted and on the basis of it, it is possible to verify if there is any relation between variables and if it is more or less exact.

The next step of multi-agent based modeling is a computer simulation, which means activating the simulation model. Simulation results (so called base flow) showing behavior of the studied system in time are compared with available knowledge about the system, and the possible verification of the model takes place. The model is verified until it reflects real system's behavior in a satisfying way. The next step of the described procedure is a simulation of potential agents behavior changes effects (during this step simulation experiments are conducted). Subsequently, base flow results are compared with experimental flow results, also the simulation results are analyzed and assessed (most frequently statistical methods are used in order to do this). The last step of the procedure is formulating conclusions resulting from the conducted research.

Summing up, multi-agent based simulation (MABS) is a relatively new approach in applications connected with investigating consumer behavior. MABS allows conducting experiments which take into consideration heterogenic complexity of both levels: individual consumer level and complex marketing environment level; it gives the possibility of modeling interactions between consumers-agents, which increases research results credibility as the modeled real world consists of interacting units; and using a computer it is possible to conduct virtually unlimited number of experiments in a short period of time (without any damage to people or environment), which allows investigating impact of many combinations of factors influencing consumer behavior (Rand, Rust 2011; Twomey, Cadman 2002). In the next part of the article there will be presented an exemplary simulation model of consumer behavior on electrical appliances market, which will allow us to show practical possibilities of applying the method described above.

## 3. Simulation model for studying consumer behavior

The study of consumer behavior is very important to the marketers because it enables them to understand and predict buying behavior of consumers in the marketplace. Multi-agent simulation is a new tool to explore the dynamics in

various kinds of systems where human behavior plays a critical role; ABS implies that a population of artificial people is constructed, thus allowing to model two critical elements of many systems in which people behave: people are different (heterogeneity) and affect each other (social interaction) (Macal, North 2006). In the presented model authors aim to understanding consumer behavior on electric appliance market by using MABS. While constructing the model, the consumers were divided into three types of consumer buying behavior: routine response behavior, limited decision making, or extended decision making (see point 3.2). Next, on the basis of this classification the approximate time that a consumer takes for making a purchase decision was defined. In the model also the influence of communication between agents and potential consumers on the potential consumers behavior change was taken into consideration. In the next part of the article there were shown the subsequent steps of the model construction.

### 3.1. Defining the research area

In the presented model authors study consumer behavior on the electric appliances market. They have chosen to study this behavior because of many reasons such as:

–  the market of electronic appliances comprises numerous product categories, without which it would be hard to imagine the life of a contemporary consumer (e.g. vacuum cleaners, irons, dishwashers, washing machines and refrigerators),
–   most people take long time before making purchase decision (the time is relatively long, in comparison with time of making decision about for example food purchase),
–  many factors influence consumer while making purchase decision, such as: marketing mix, psychological, social and economic factors.

The data employed to analyse the factors influencing consumers' purchase decision-making processes were obtained through a questionnaire that was conducted in December 2011 in Basra, a city in southern Iraq. It is worth mentioning that there are few studies related to this kind of products and this is the first study which has attempted to explore the growing electric appliances market in this country. In Iraq there are not many researchers who are interested in consumer behavior as well as scarce and inadequate research performed in this area. Researchers working on the topic of consumer behavior and competition in

the Iraqi market are Abood Al-Janabi (2000), Abo Ahmad (2004), Ibrahim and Husin (2009).

## 3.2.  Defining consumers-agents characteristics

Agents in market models typically represent people, companies, branches, dealers, projects etc. Each agent has its variables, parameters, behaviors. There may be a network of contacts between agents which is used to model the exchange of relevant information. There also can be an environment affecting the agents and being affected by them.

In the model it is supposed that the agent is a consumer because the consumer is a cornerstone of successful marketing and in this model authors wanted to explore types of consumption behavior of Iraqi consumers on electric appliances market. This study can help in a deeper understanding of the impact of different factors on consumer buying behavior. This model is created to analyze the relationship between independent variables, such as culture, social, personal, psychological and marketing mix factors, and the behavior of consumer as a dependent variable in electric appliances market.

Studies suggest that customers go through a five-stage decision-making process in any purchase. This is summarized in the Figure 4. The model implies that customers pass through all stages in every purchase. However, in more routine purchases, customers often skip or reverse some of the stages. The buying process starts with need recognition. At this stage, the buyer recognizes a problem or need or responds to a marketing stimulus. Then the consumer needs to decide how much information (if any) is required. If the need is strong and there is a product or service that meets the need close to hand, then a purchase decision is likely to be made there and then. If not, then the process of information search begins. A customer can obtain information from several sources: personal sources (family, friends), commercial sources (advertising, retailers, packaging), public sources (newspapers, magazines, radio, television, Internet). The usefulness and



Figure 4. Consumer Buying Decision Process

Source:  own elaboration based on: Pride, Ferrell (2007, pp. 177–179).

influence of these sources of information will vary by product and by consumer. It is worth noticing that marketers today have greater control over the information provided (or not provided) to consumers and the manner in which this information is presented (Kivetz, Simonson 2000).

In the evaluation stage, the customer must choose between the alternative brands, products and services. An important determinant of the extent of evaluation is whether the customer feels "involved" in the product. Buyer's level of involvement determines why she is motivated to seek information about a certain product or brands and virtually ignores others. Involvement level, as well as other factors, affects a person's selection of one of three types of consumer buying behavior: routine response behavior, limited decision making, or extended decision making (Pride, Ferrell 2007). Table 1. presents a comparison between them.

Table 1

Comparison Between Types of Behavior

|  | Routine response behavior | Limited decision making | Extended decision making |
|---|---|---|---|
| Level of involvement | low | low | high |
| Product cost | low | low to moderate | high |
| Brand preference | more than one is acceptable, although one may be preferred | several | varies, usually many |
| Search effort | little | little to moderate | extensive |
| Time spent | short | short to medium | long |

Source: own elaboration based on: Pride, Ferrell (2007, pp. 177–179).

While working on the simulation model for each consumer represented by single agent there were defined parameters typical of him such as: gender, age, education, income, and fourteen behavioral attitudes. Subsequently, on the basis of empirical data there was created a base of agents behavior rules. Finally, based on parameter value and behavior rules the agents were divided into three groups:
– potential consumers who have extensive behaviour,
– potential consumers who have routine behavior,
– potential consumers who have limited behavior.

### 3.3. Designing the main state charts

For the conceptual design of agents authors have used state charts. State charts show the different states an entity can be in, and define the events that cause a transition from one state to another. This is exactly the information which is needed in order to represent agents later within the simulation environment. Furthermore, this form of graphical representation is also helpful for validating the agent design because it can be easily understood by non-specialists. Figure 5 presents one of the state charts of consumer, in this case for a consumer agent (transition rules have been omitted for simplicity). When consumer enters the market he or she is in potential consumer state. In this state which simply link with three states. She or he will probably take one transaction depends values of parameters and rules. In this state consumer does not spend any time, but the time spend where the transaction between limited routine or extensive state and consumer state because the time for making purchase decision depends on types of consumer behavior. For instance the consumer who have extensive behavior spends longer time for collecting information before making decision comparing with consumer who have limited or routine behavior.
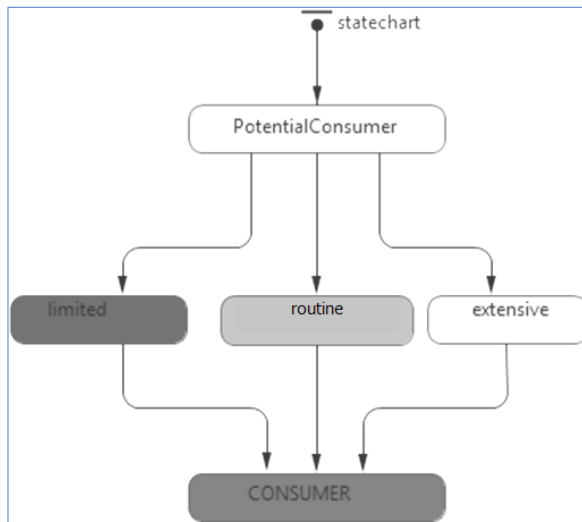


Figure 5. Consumer State Chart

Source: own elaboration.

### 3.4. Defining interactions between agents

Marketing firms and departments use communication to target specific groups of consumers and influence them into buying a particular product. Sometimes, these firms and departments are unnecessary as word of mouth from consumers creates a buzz and others will purchase goods or use services based on the recommendation of peers. Beyond word of mouth, companies will use advertisements and sales people to communicate to target markets and attempt to influence them into purchasing products. Word of mouth buzz for a particular product or service is typically organic and does not come from a company or business. This happens when a certain demographic latches onto a brand or product and, in turn, tells their friends and/or family about it. In MABS the information exchange between the agents (word of mouth) is modeled explicitly as periodic "contact" events resulting in contacting individuals variables change (Garifullin et al. 2007).
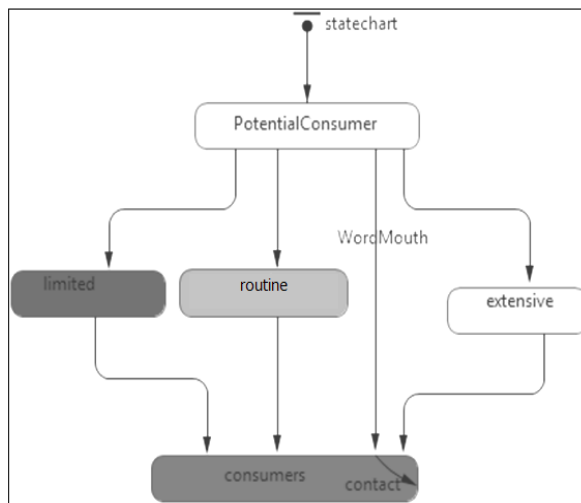


Figure 6. Communication between agents

Source: own elaboration.

In the described model authors have added agent communication – word of mouth. They have supposed the consumers contact each other. A consumer contacts on average with two persons per day. During these contacts the consumer

of product may influence potential consumer and the potential consumer will want to buy this product after contact. In Figure 6 authors have added a cycle transaction in consumer state. This transaction will be taken periodically and on each occurrence the agent – consumer will be sending a message to some other random agent saying "buy it" or "good product". If another agent is potential consumer (i.e. is in the state potential consumer), he or she will react to such a message by changing their state to consumer. Obviously, it was achieved by adding a transaction from potential consumer to consumer called "Word Mouth" trigged by the corresponding message.

## Conclusions

Considerations presented in the article allow drawing a conclusion that multi-agent based simulation is a method which can be and is successfully applied to study consumer behavior. On the simulation model constructed in accordance with the suggested procedure it is possible, using appropriate simulation packet (e.g. AnyLogic, Swarm, NetLogo), to conduct virtually unlimited number of experiments in a short period of time (without any damage to people or environment), which allows studying the influence of many combinations of rules being the basis of consumer purchase decision.

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**KONCEPCJA WIELOAGENTOWEGO MODELU SYMULACYJNEGO
DO BADANIA ZACHOWANIA KONSUMENTÓW**

**Streszczenie**

Celem artykułu jest zaprezentowanie koncepcji wieloagentowego modelu symulacyjnego do badania zachowania konsumentów. W artykule przedstawiono istotę symulacji wieloagentowej oraz procedurę wieloagentowego modelowania symulacyjnego, na podstawie której opracowano założenia teoretyczne do budowy modelu symulacyjnego zachowania konsumentów na rynku urządzeń elektrycznych.

**Słowa kluczowe:** zachowania konsumentów, proces podejmowania decyzji, symulacja wieloagentowa, model symulacyjny