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Simulation Model of a Company System

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ABSTRACT

Simulation models provide an opportunity to experiment with alternative management solutions. These experiments can be done before designing or making changes to a system to clarify how the system will react to a change in the structure and the rules of operation.
The company system is a complex system operating under conditions of uncertainty. Its life cycle is the process of passing through multiple system states.
Through statistical tests and with the help of the created simulation model of a company system, experiments are carried out under different scenarios and management decisions.

Keywords: Company system, Simulation models, Company life cycle.

1. INTRODUCTION

When designing and managing a company, there is a constant need to adopt one or another management decision. With multivariate management decisions, with the uncertainty of the company's surrounding environment, managers need more reliable means when choosing and justifying their choices. When their intuition and experience are not enough, they turn to more rigorous methods.

The task is to create a suitable methodology for researching the company system, which will provide an opportunity to analyze different scenarios for its functioning.

The analysis and conclusions for each scenario would provide the managers with the security and justification they need when choosing one or another management decision [5,8].

2. THE SYSTEM APPROACH AND THE POSSIBILITIES OF SIMULATION MODELING IN THE STUDY OF THE COMPANY'S ACTIVITY

We define the company as a system, which we call the company system. The basis for this is given by the understanding that the company is a set of elements that possess the necessary and sufficient conditions for determining as a system:

- has a specific structure - company structure;
- the external environment influences the company, and it influences the environment;

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- there are quantitative characteristics that determine the state of the company at any moment in time;
- the company changes its status over time;
- random factors are involved in the company's functioning [9,12,13].

The company system is a complex system functioning in conditions of uncertainty due to the influence of random factors.

The complexity of the interrelationships in the system itself, of the interrelationships between the structural elements of the company system and the processes influencing its functioning, poses the question of choosing an appropriate research method [5,6,12].

The presence of random factors affecting the company system determines its probabilistic nature. When investigating the influence of random factors, the data obtained statistically, it is appropriate to apply statistical modeling. Dynamics, the transition from one state of the system to another, implies using the possibilities of imitation, applying imitation modeling. When it is difficult to theoretically study the structural elements and the observed relationships and dependencies, in the case of a company system, their experimental establishment is a reasonable means. From our point of view, the appropriate research method is simulation modeling of the company system.

The model that reproduces the structure, the interrelationships between the elements of the company system, and the dynamics over time is a simulation model of the actual company system. Its advantage is that through it, a logical-mathematical experiment is made, and not an actual experiment.

If the model adequately reflects its actual prototype, then in the process of realization of the simulation model, the necessary information is given about the behavior of the studied company system under one or other starting conditions under different scenarios. A significant advantage is that changing the parameters with the simulation model is possible and permissible, which is impossible in reality [1,2,7].

From our point of view, the application of the systems approach in the study of the company, combined with the possibilities of simulation modeling, represents an excellent opportunity to study the main interrelationships and dependencies between the structural elements of the company system, between the system and other systems, to study the dynamics of the system, and also of the processes affecting its functioning.

3. MODELING THE COMPANY SYSTEM

The object of modeling in this study is the firm's life cycle. We consider the object of modeling as a set of states of the firm and a sequence, a series of transitions from one state to another. The change in the state of the company is the result of the occurrence of certain events. The probability of transition from one state to another is different. It depends on the nature of the condition itself and the length of stay in it. The set of possible states of the firm in its life cycle affects the firm's environment and is affected by it.

The quantitative characteristics that determine each state of the system are significant in number. We select only the most essential ones. The dynamics of the company system are expressed through the transitions, through the transition from one state to another. Transitions occur under the influence of random factors, also subject to modeling.

From what has been said so far, it can be argued that the firm's life cycle has the characteristic features of a system and can be the subject of simulation modeling. In the simulation model of the firm's life cycle, we consider it appropriate to use Markov chains, which are realized by statistical tests. In its life cycle, the firm passes through several N possible states. The sequence of states represents the company system's realization or the company system's trajectory. It is necessary to establish whether there is a dependence between the individual states in the series.

As a result of analyzing a large volume of statistical data, we concluded a simple

relationship, a one-step dependence, under an arbitrary combination of possible states. Therefore, the life cycle can be modeled with a simple Markov chain. Any realization of the system will be equivalent to a realization of a simple Markov chain.

In the research process, the question arose whether transitions from one state to another depend on temporal characteristics. Insofar as the life cycle is a process of firm creation, growth, decline, and cessation of activity and, i.e., an "aging" process is observed, a non-uniformity of the Markov chain modeling the life cycle can be inferred.

Since such a chain is complicated to use, even with a small number of states, we consider it expedient to replace a complex chain with a sequence of several uniform Markov chains [1].

We use a set of m simple uniform Markov chains to simulate the firm's life cycle. We choose the time intervals to be ten years. With the dynamics of economic processes at the beginning of the 21st century, choosing a longer interval would be incorrect, in our opinion.

Each 10-year interval of the company's operation is modeled with a separate simple Markov chain. Each circuit is a realization of the system of states in the ten-year interval. [9,10,11]

If we accept the hypothesis of a uniform distribution, in the ten-year interval, of the random variables affecting the company's activity, then for each interval, one matrix of one-step transition probabilities can be used.

Thus, at every kth ten-year interval, we compare a matrix of transitions $P_{(k)}$. The elements of the matrix P_{ij} express the probabilities of the possible transitions from one state A_i to another state A_j. It is permissible for the system to remain in the same state over the ten-year interval. Each probability of the possible transitions is calculated as a statistical probability.

We use a transition probability matrix as a function of time. For each time interval, different values are assumed for its transition probabilities. Thus k matrices are formed. Probabilities are conditional probabilities, with the simultaneous occurrence of dependent events, within an interval and probabilities are unconditional probabilities of the simultaneous occurrence of independent events within an interval.

We apply the method of statistical tests using transition probability matrices $P_{(k)}$ and cumulative probability matrices $P_{(k)^k}$.

The test starts from the initial state A_1, i.e. from the moment of generation of the idea and creation of the company. This is the beginning of the first uniform Markov chain. The corresponding elements of the cumulative matrix are compared with a computer-generated pseudorandom number to determine which other state is transitioned to at this step or the system remains in the same state.

Reaching the final state A_n - termination of the company's activity, the trial ends. Move on to the next test. The test can also end when a certain, pre-fixed, time is reached.

By accumulating a sufficiently large number of trials, called model realizations, we can infer the quality of the firm's life cycle model.

The complexity of simulating heterogeneous processes often leads to the need to create not one but a set of models. The advantage over a very complex model is the ability to combine different types of models [8,13].

According to our concept, it is appropriate to consider the company system as a complex system comprising many subsystems. The production system, the logistics system, the financial system, the personnel system, and the marketing system are some of the most critical subsystems of the company system.

Each can be modeled as an independent system, and a separate model can be created. The models thus obtained are integrated into a complex set of models of the company system, in which the model of the life cycle of the company is central. The satellite models reflect the action of specific processes affecting production, logistics, finance, human resources, etc.

At each stage of the firm's life cycle, different subsystems of the firm's system behave differently. It can be modeled using the results obtained from the central model as inputs for the subsystem models.

The connections between the models are of the output-input type, since the output parameters of the central model are the input parameters for a certain subsystem. The unification of the models is suitable to be realized in the form of a star. Various subsystems of the company system can be included as satellite models, e.g., "logistics system", for which a suitable model was developed in the article by P. Naydenov [2,13].

4. LIFE CYCLE OF THE COMPANY

Adopting the perspective in the theory of the life cycle of a firm of Adizes [3], we use the defined phases in this theory. Each phase corresponds to a state of the firm A_i.

According to Adizes, the company's age does not depend on lived years. Regardless of age, a company can be young and energetic or old and clumsy. The actual age depends on flexibility (manageability) and control (self-control). It is characteristic of the young company that it is flexible and uncontrollable. For the old one - lack of flexibility and strong control. When control prevails over flexibility, the firm becomes old [3].

Adizes clearly defines the processes of growth and aging. Growth is the ability of the firm to face and solve different problems. The encounter at the beginning with small, and over time with increasingly large, problems is characteristic of the company's development.

Aging is characterized by a decreasing ability of the firm to deal with problems. When a balance between control and flexibility is achieved, the company is at its best. If the balance is constantly maintained, the company can remain in the boom phase for a long time.

The phases in the life cycle theory of Adizes [3] are the basis of the states A_i in our central model.

A1 - Generating the idea (looking around, courting)

Birth of the business in the form of an idea. The emphasis is on ideas and business creation opportunities. At this stage, there is more discussion than actual action. Different opinions are gathered about the idea. The entrepreneur is motivated to realize it, to take the risk of creating a new business. When the idea receives a positive evaluation, the company is created.

A2 - Baby age

The focus shifts from the idea to the results, to what extent they satisfy the needs for which the company was created. The requirement is to have a hard-working, results-oriented creator, not a dreamer. The organization is identified with its creator. At this stage, there is no system for searching and selecting personnel for evaluating the performance of tasks. Characterized by hard work to achieve quick results in the form of sales revenue. For the company to survive, it is necessary: 1) a periodic supply of working capital and 2) unconditional dedication of its creators - the entrepreneurs. The company ultimately depends on them.

A3 - Childhood

The idea begins to give results, the cash shortage is overcome, and the level of sales is constantly increasing. The vision of the company's future is changing - from a minimal range to almost infinite possibilities. The company is organized around people, not around tasks. The company's behavior is reactive - it reacts to the opportunities provided by the external environment, but it cannot predict them.

A4 - Adolescence

The company is born a second time, but this time spiritually. A distinctive feature of the company's behavior is conflicts between old and new associates and goal contradictions. Business outgrows the individual abilities and capabilities of its creator. There is a need to delegate rights and responsibilities. The professional manager appears, leading to a change in the company's management system. The manager's task is to solve current issues and prepare the company to meet and solve new problems. The goal is shifting from extensive development to increasing the quality of the activity.

A5 - Flourishing

At this stage, the organizational structure is built, the official duties are clarified, and the prospects for development and creativity are institutionalized. The company is results-oriented, and customer needs are met. It deals with planning and predicting the future. At this stage, sales and profit growth is realized. A

system of subsidiary organizations is created. The prosperity indicates the company's viability and ability to achieve effective results in the short and long term.

A6 - Maturity (stabilization, plateau)

This is the first stage of aging. The stable company has low expectations for future growth for the conquest of new markets and technologies. The company concentrates on its past achievements and not on the future. The company is suspicious of any changes. In it, performers are encouraged, not innovators, and security is sought. Staff are more interested in interpersonal relationships than business development and risk. The spark, the generator of processes, decisions, and actions, is already a smoldering flame. The company prefers to stick to proven products or services because it has the necessary financial resources. There are almost no new products, or if there are, they complement existing products. Leaders prefer not to take risks and seek change, they stick to the proven. An insignificant amount of innovation is generated, which is not enough to realize something revolutionary.

A7 – Late maturity (aristocracy)

It is characterized by spending funds on strengthening the control and insurance system instead of innovation. The focus of the activity shifts to how things are done rather than what and why it is done. It relies on traditions and introduces formalism in clothing and communication. Only individuals still care about the viability of the firm. There is almost no interest in conquering new markets. Expectations for further growth are declining. The company has significant cash resources. The horizon is short-term, as the goals are oriented toward financial stability and minimal risk.

A8 – Sunset (Early Bureaucratization)

It focuses on the problem rather than the action to be taken. There are various conflicts in the company - interpersonal, between different departments and structures. Vimanation is aimed at internal disputes, not external users. Managers are committed to finding the culprit of problems, not solving them. Attention is directed inwards to the organizational system itself, due to which the competition quickly gains an advantage. There is no teamwork, and everyone fights for personal survival and benefits. Managers leave en masse due to incorrect evaluation of their work. In the eyes of the rulers, they are the cause of this condition, which is their biggest delusion.

A9 Late Sunset (Late Bureaucratization)

The company is artificially kept alive. It does not create the necessary resources for self-preservation. There is no orientation to the result, no desire to change.

There is no working team, but there is a system, rules, prescriptions, and procedures. The company is concentrated only on itself. Mindless control exists. Not enough resources are generated for the firm to be independent. Its continued existence is due to an external cause, such as a government agency, business entity or corporation. Communication with the outside world is through very narrow channels. It serves a narrow range of customers and does not seek new ones that would provide additional value.

A10 - Death

This stage may not occur suddenly if the firm is supported for political reasons by the state, for example, to preserve jobs and employment. But if the company completely depends on customers, its death occurs quickly. If it is not helpful to them, they forget about it.

5. CONSTRUCTING THE TRANSITION MATRIX

Each phase of the company's life cycle has a different duration, determined by the specifics of the activity.

The research question arises, how does the firm transition from one state to another? What are the characteristics of the event that cause this transition? Analytical methods cannot give a universally valid answer.

At every kth ten-year interval, we map a matrix of transitions $P_{(k)}$. The elements of the matrix P_{ij} express the probabilities of the possible transitions from one state A_i to another A_j. It is also permissible for the system to remain in othe samestate in the ten-year interval. Each

probability P_{ij} is calculated as a statistical probability.

We use a transition probability matrix as a function of time. For each time interval of ten years, different values are assumed for its transition probabilities. Thus, k number of concrete matrices are formed.

The probability P_{ij} of a transition from each state A_i to each state A_j is calculated as a statistical probability. For this purpose, we use information about a large number of companies. For timpossible transitions the transition probability P_{ij} has the value 0. The firm remaining in the same state has the value 1.

Collecting and processing statistical information for many companies is the most time-consuming task. The lack of information about the listed ten states of the companies from the country or region under consideration necessitates a marketing survey on the spot, which could be carried out according to the methodology presented in the article by V. Boeva [4].

In our research, the approach was as follows: We studied 100 companies operating from January 1, 1990, to January 1, 2023, selected by random sampling. We conducted a direct personal interviews with the managers of the companies. The interview questions were related to the status as of January 1 of each year from the time of the company's establishment until January 1, 2023, or until the company ceases to operate. Once they were familiar with the main characteristics of the life cycle phases, they determined, by expert means, the phase in which the particular firm was located on January 1 of each year.

In this way, the beginning and end of each life cycle state for each firm was determined, according to the survey of managers. Average values for firm residence times in each state were calculated.

For each year and each state, the number of firms that remained in the same state as well as the number of firms that moved to the next life cycle state was determined.

The calculations made are the basis for determining the transition probabilities P_{ij} of the matrix $P_{(k)}$. In case of impossible transitions, the value of P_{ij} is 0. The matrices thus obtained, as well as the cumulative matrices $P_{(k)^k}$, make it possible to do computer experiments using the method of statistical tests.

Four matrices of transition probabilities were obtained, in which the P_{ij} values are different and correspond to the specifics of the considered period.

The resulting matrices corresponding to the periods are:

$P_{(1)}$ for the period 01.01.1990-01.01.2000;
$P_{(2)}$ for the period 01.01.2000-01.01.2010;
$P_{(3)}$ for the period 01.01.2010-01.01.2020;
$P_{(4)}$ for the period 01.01.2020-01.01.2023

They correspond to the sequence of the four Markov chains.

Through the sequence of these matrices, the creation and development of a particular firm can be imitated. Each trial mimics the development of a firm, starting from the initial state - the creation of the A_1 idea. A computer generates a series of pseudorandom numbers R_i, uniformly distributed in the interval (0,1). At each step of the model implementation, the corresponding random number from the sequence is used to determine the transition from state A_i to the next state A_j.

We consider a simple uniform Markov chain with the transition matrix $P_{(k)}$ and the cumulative matrix $P_{(k)^k}$, which in this case are the following:

$$P_{(k)} = \begin{vmatrix} P_{1,1} & P_{1,2} & P_{1,3} & \ldots, & P_{1,10} \\ P_{2,1} & P_{2,2} & P_{2,3} & \ldots, & P_{2,10} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ P_{10,1} & P_{10,2} & P_{10,3} & \ldots, & P_{10,10} \end{vmatrix} \quad (1)$$

$$P_{(K)^K} = \begin{vmatrix} P_{1,1} & P_{1,1}+P_{1,2} & P_{1,1}+P_{1,2}+P_{1,3} & \ldots, & P_{1,1}+P_{1,2}+P_{1,3}+\ldots+P_{1,10} \\ P_{2,1} & P_{2,1}+P_{2,2} & P_{2,1}+P_{2,2}+P_{2,3} & \ldots, & P_{2,1}+P_{2,2}+P_{2,3}+\ldots+P_{2,10} \\ \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots & \ldots\ldots \\ P_{10,1} & P_{10,1}+P_{10,2}P_{10,1}+P_{10,2}+P_{10,3} & \ldots, & P_{10,1}+P_{10,2}+P_{10,3}+\ldots+P_{10,10} \end{vmatrix} \quad (2)$$

We introduce the following notations for the elements of the commutative matrix:

$$L_{1,1} = P_{1,1} \quad L_{1,2} = P_{1,1} + P_{1,2} \ ,\ldots, \quad L_{1,10} = P_{1,1} + P_{1,2} + P_{1,3} + \ldots + P_{1,10}$$
$$L_{2,1} = P_{2,1} \quad L_{2,2} = P_{2,1} + P_{2,2} \ ,\ldots, \quad L_{2,10} = P_{2,1} + P_{2,2} + P_{2,3} + \ldots + P_{2,10}$$
$$\vdots$$
$$\vdots$$
$$L_{10,1} = P_{10,1} L_{10,2} = P_{10,1} + P_{10,2}, \ldots, L_{10,10} = P_{10,1} + P_{10,2} + P_{10,3} + \ldots + P_{10,10} \quad (3)$$

1. Depending on the interval formed by the elements of the cumulative matrix, in which the random number R_i falls, it is determined in which state the company moves to the corresponding step.
2. The calculation algorithm is called "determining the outcome of the trial by lot."
3. The initial state for the test A_i is set. It specifies the row of the matrix $P_{(k)}$. to be used and the values L to which the comparisons will be made.
4. The next pseudorandom number R is generated.
5. Compare R with L_{i1}
6. If R < L_{i1} holds, the system remains in the same state. If it is not met, it goes to a comparison with L_{i2}.
7. Compare R with L_{i2} . If $L_{i1} \leq R_i < L_{i2}$is valid, the system goes to state A2. If not met, proceed to comparison with $L_{i3}$and so on.
8. It continues until the condition L_i, m-1 ≤ $R_i < L_i$, m is met. The system goes into the A_m state.
9. The A_m state becomes initial for the next realization.

A series of states is obtained through which the firm passes at each step, and in this case the step is one year.

The implementation of the model ends when a fixed moment is reached, for example 01.01.2023, or when the company ceases to operate.

How adequate the model of reality is can be checked by comparison with the data from the National Statistical Institute, Business Demographics section.

The National Institute of Statistics data is not as detailed as the ten phases of the business life cycle discussed here. There is information on the number, births, longevity and deaths of companies by year, size, type of legal form and economic activities. They make it possible to make a comparison with the simulation results. From the comparisons made, it was found that there was some bias in the model due to the small sample of 100 firms that were surveyed. With the adjustments made in the transition probabilities Pij, the model started to give satisfactory results of the calculations.

6. CONCLUSION

The proposed system of simulation models expands the possibility of studying the company and the processes that take place in it.

Through the successful implementation of the proposed model, it is expected to improve some factors that will be favorable for companies such as: Leadership; Strategy and Planning; Human capital; Partners and Associates; Resources and Processes.

This will improve the general framework for the quality of management, organization and work in each company and will provide a new opportunity-based approach to the successful development of company strategy.

The authors are of the opinion that using the capabilities of the controlled experiment with the model of the studied system enriches the methodology for the study of these processes and helps to make informed management decisions.

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