System-Dynamic Modeling of Information Influences and Co-Operations

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Abstract. The questions of structural-functional and structural-dynamic modeling of information influences and counteractions in the economic sphere are considered. The basic models are presented in the form of a system of differential equations in the notation of system dynamics, as well as in the form of context and child DFD diagrams realized in accordance with SADT technology. Based on the developed hierarchical set of models, experiments have been implemented using the Anylogic simulation platform and real statistics on the practical activities of functioning business structures to promote goods and services in a competitive market environment. The structural-functional and structural-dynamic models of information influences and counteractions developed by the authors in the economic sphere have been successfully tested. A high degree of consistency of modeling results with empirical data is provided, which makes it possible to forecast, analyze, and manage various scenarios for the implementation of the corresponding processes.

Keywords. Structural-functional modeling, system-dynamic modeling, information impact, information counteraction, management in the economy.

1 Introduction

Modeling the functioning of complex management systems in the economy, as well as all possible processes related to the presence of information impacts (II) and information counteractions (IC), allows to predict the behavior of objects and subjects of management in an aggressive information environment. In addition, it contributes to an adequate assessment of the possible positive or negative consequences of the implementation of such impacts.

In the modern information society, competitive struggle in the economic sphere is realized using the means of information and telecommunication technologies. Quite often the opinion about a product or service is formed through the implementation of carefully planned information influences on certain groups of consumers who are participants of various social networks, subscribers of various mailings, readers of Internet blogs, etc. At the same time, due to the dissemination of the aggregate of information, a certain positive attitude to the product advertised in this way can be formed, as well as negative (conditionally speaking, advertising and anti-advertising). In addition, there are also a number of Internet strategies to neutralize negative information impacts, called the information countermeasures.

The foregoing allows us to state that the modeling, assessment and forecasting of information impacts on social groups, with a view to realizing competitive struggle in the economy, and the organization of an appropriate information counteraction are actual management tasks.

2 Degree of Problem Development

Nowadays, a scientific base has been created in the field of dynamic modeling of information influences on various social groups, which makes it possible to investigate the processes of so-called information "infection", depending on the degree of influence of various external and internal factors [2-5]. Several types of such models have been developed: topological, factorial, regression, probabilistic and others. They are the basis for further improvement of the toolkit for modeling information interactions in society and the economy.

Some authors in their publications argue that the most effective, from the point of view of practical application, are simulation methods of modeling information impact on groups of intellect carriers (both natural and hybrid). They allow you to analyze various scenarios for implementing information operations and successfully predict the behavior of both objects and control systems [1, 5].

At one time, the authors of this article have also developed similar models that have found real application in a number of industries (telecommunications, computer networks, digital economy, education, etc.) [6, 7]. At the same time, the basis for implementing simulation in practice was a set of interrelated models of system dynamics synthesized by the implementation of a deep analysis of branched, nonlinear dynamic structures. And as a theoretical basis system dynamics developed by J. Forrester was used [8].

The success of the above actions, as a rule, is determined by the thoroughness of carrying out the structural-functional and structural-dynamic analysis of processes. In this case, it is important to adequately establish the presence and nature of the interrelationships between the individual elements and their groups, the stable and unstable state of the objects, the nature and parameters of the information processes, the functions and operations that are realized, as well as the necessary resources and constraints (regulations, rules, etc.) .). To solve the above tasks, according to the authors, it makes sense to use the technology of SADT (structural-functional modeling) and the corresponding software products, in particular CA ERwin Process Modeler.

3 Purpose of the Research and Methodology

Thus, the purpose of this study is the development of appropriate models of information operations related to targeted information impact in the sphere of the economy, on the one hand, and information counteractions (IC) on the other.

We formulate a number of definitions that are directly related to the subject, purpose and objectives of this scientific research, as well as the methodology that defines it. Network information operations are a set of interrelated, purposeful actions of information character, carried out in complex hierarchical information systems and computer networks, through the implementation of "subject-object" and "object-object" contacts and task-oriented tasks, in fact, to initiate, update, block, generate information processes in the technical, technological, economic and social spheres.

System dynamics has evolved, thanks to advances in the analysis and design of complex control systems, and in the field of computer modeling and computational methods. Its basic principles were developed by J. Forrester, whose scientific works were devoted to the analysis of the processes of functioning of industrial enterprises, development of cities and world dynamics [8]. A structural-functional modeling (SADT - structured analysis and design technique) is a set of methods, rules and procedures designed to construct functional models of systems in different subject areas.

The SADT model displays the structure of the functioning processes of the system and its individual subsystems, that is, the actions performed by them and the connections between these actions. For this purpose, specific models are synthesized, which, in a visual form, represent these actions in the form of a corresponding hierarchy. The fundamentals of structural-functional modeling technology were formulated at the end of the 1960s by Douglas T. Ross, while solving problems related to structural programming [9].

Now there is a wide choice of means of automated support of technology SADT. Initially they were used for integrated computerization of production, and now they found application in various fields of activity, primarily in the economy. Support for SADT has evolved from a simple graphical tool to software that operates on the basis of knowledge of more general concepts of modeling. These tools have the ability to understand the semantics of the interconnected network of SADT diagrams and a variety of models, and to combine such a multitude of information and rules with other technologies.

Thus, the authors propose to solve the problems of management in the sphere of the economy by implementing a set of information impacts and counteractions, and integrated approach is to use two approaches - structural-functional and system-dynamic modeling. Moreover, the results of the implementation of the first component will determine the structure and content of the set of actions within the framework of the second one.

4 Modeling of Information Impacts and Counteractions in the Sphere of Economy

The high level of complexity of the simulated processes, the dynamics of the corresponding parameters, states and structure predetermines not only the multiplicity of modeling objects and the hierarchy of interrelations between them, but also the need to form a hierarchy of models that describe objects, processes, relationships, resources and performance results. The links between the above models and their hierarchy are displayed using a set of graphs.

And directly for the models of system dynamics, the following structural elements are characteristic: levels are controlled objects displayed by variables whose values correspond to the integral characteristics of the real flows under consideration; rate is the speed of flows emanating from certain levels and entering into others, which determine the corresponding changes in them; decision functions are functional dependencies existing in the system, as well as auxiliary values and constants. Phase variables (system levels) are displayed using systems of differential equations [7].

Based on the analysis of scientific literature, we assume that the above-mentioned tasks of modeling information impacts in the economy are actually congruent with the tasks of ensuring information security in general and in computer networks in particular. Synthesis of such models is realized by a number of foreign scientific teams of the USA [1, 2], China [3], Korea [4] and other countries successfully applied in practice. However, they require conceptual and methodological refinement to solve similar problems in the economic sphere effectively.

As the experience of applying the principles of system dynamics for modeling shows, the initial node of graphs displaying the hierarchy of dynamic information models is the basic system-dynamic model of SY (S is the number of objects of information impact, and Y is their number of positively reacting to it). In addition, SYR, SLY and SLYR models are developed that contain other states (R is the number of objects that ignore the imposed behavior, L is their number in the latent stage, etc.), as well as models that reflect the dynamics of the volume of a group of objects influence (the presence of the symbol "O" in the abbreviation), and ignoring objects after some time, behavior imposed to them and returning them back to the original set of prone II (the symbol "S" in the abbreviation). Examples of such graphs containing 16 models are given in the publication [5].

Each of these models can be of two types. In models of the first type it is assumed that an object that has adopted a negative idea of influence cannot change the behavioral algorithm and directly go to the set of objects that have adopted a positive idea, and vice versa. Only the possibility of forgetting information and the transition of an object that has adopted a positive or negative idea of information impact into the original set is envisaged. After this, the object can again accept both a positive and a negative idea. Models of the second type are modifications of models of the first type and imply a direct transition of the object that adopted the first (negative) idea of II into the set that accepted the second (positive) idea of II and vice versa.

The complex system-dynamic model is represented by us in the form of the following system of equations

$$\dot{q} = f(q, \varepsilon) \quad (1)$$

where $\dot{q} = \frac{dq}{dt}$; t is time; $q = \text{colon}(q_1, q_2, q_3)$; $f = \text{colon}(f_1, f_2, f_3)$; $\varepsilon = \begin{pmatrix} \varepsilon_{11} & \varepsilon_{12} & \varepsilon_{13} \\ \varepsilon_{21} & \varepsilon_{22} & \varepsilon_{23} \\ \varepsilon_{31} & \varepsilon_{32} & \varepsilon_{33} \end{pmatrix}$ are II parameters; q_1 is the total number of objects subject to information impact (and counteraction); q_2 is the number of objects that received the service (goods); q_3 -is the number of objects that refused services (goods); $f_i(q, \varepsilon) = \varepsilon_{i1} q_1 + \varepsilon_{i2} q_2 + \varepsilon_{i3} q_3$. Values ε_{ij} characterize all possible parameters of information impacts and counteractions, given in fig.1-4. These include the propagation speeds of competing impacts; speed of decision-making by II objects (order execution or refusal from it); relative frequencies of ordering and refusal; the length of the latent period; probability of forming a positive (negative) message, etc. Generally speaking, the parameters can depend on the time, but here we consider them constant. It should also be noted that in system (1) implicitly there is a value $q_4 = q_1 - q_2 - q_3$ characterizing the number of II objects that have not taken any decision at the moment (in the latent stage).

For the practical implementation of such system-dynamic models, as a rule, statistical data are used on the distribution of various information impacts in social networks, as well as survey data in groups of such networks. The process of simulation is carried out on the platform Anylogic or similar [10].

We use the tools of the CA ERwin Process Modeler for the SADT technology to synthesize structural and functional models for the implementation of information impact and counteraction processes in the economy. To simplify the situation, it is assumed that there are two competing market players, each of which "promotes" its product (service) on the market, carrying out information impact on a certain social group of intellect bearers. Simultaneously, an information counteraction to the competitive proposal is formed.

The DFD diagram of the information impact on a group of objects that belong to a certain group (for example, one of the groups of a certain social network) is shown in fig. 1.

In this figure, a market participant is presented, initiating, due to information impact, the processes of acquiring certain goods or receiving services. Choosing the target audience and the means of influencing it, he turns to sources of information on available modern methods, technologies and means of implementing II, as well as on the availability of potential II facilities and their groups. In doing so, it assesses its capabilities and resources to implement these impacts, receiving information from relevant sources.

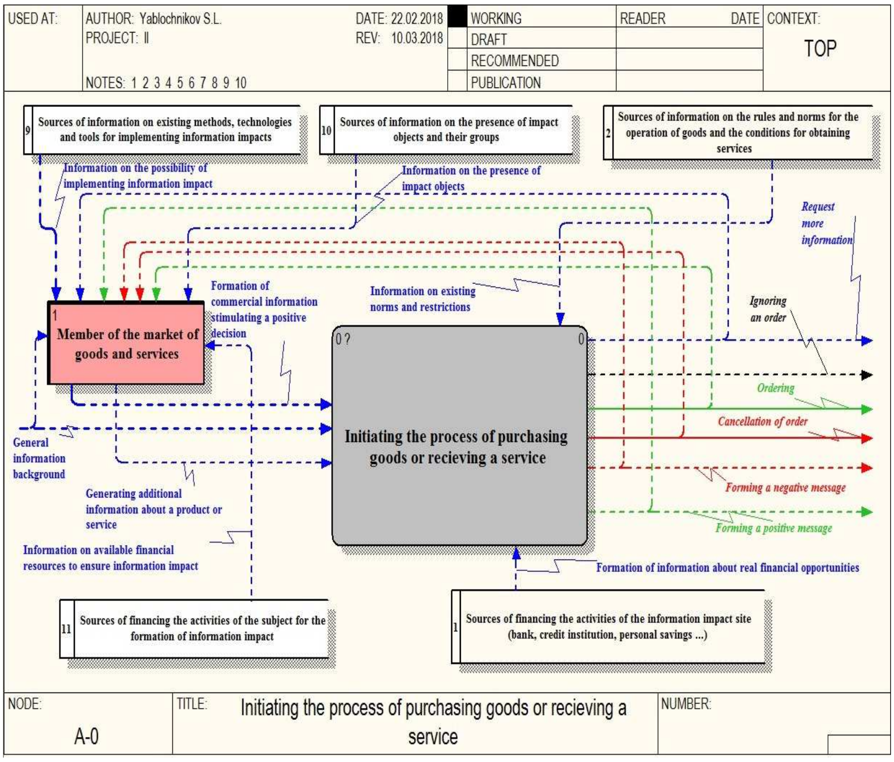

Fig. 1. The diagram of the implementation of II on a group of objects

In turn, the very process of stimulating the activity of market participants, initialized by this subject, can have several outcomes: the formulation of an order and the receipt of goods or services; refusal to order; ignoring the offer. In addition, objects "infected" due to II can themselves become sources of initialization of II for other objects, spreading either positive or negative messages. II objects, in the process of making an appropriate decision, use sources of information on the rules and norms for the operation and the procedure of operating of these goods and services, as well as on available finances and various payment schemes for goods and services. In addition, it is possible to request additional information from a market entity.

Fig. 2 shows the decomposition of the main process (Fig. 1) as a daughter DFD diagram. First of all, the information object, which in a certain way is allocated on the general information background, should be presented in a certain way to the object of influence. They should interest him, to go to the decision-making phase, or at least to implement some analysis. (for example, assessing the competitive environment). At this stage, we focus on three main processes: the adoption of a preliminary positive decision; rejection of a commercial proposal and perception of the whole information without further action (latent stage).

In the first case, the object of information impact begins to analyze the market carefully, while correlating available financial resources (cash and non-cash funds, the possibility of lending or other methods of payment for goods and services, for example, discounts, promotions, bonuses, etc.).) and a set of characteristics, information, about which he requests from the subject forming the II. The information about the current norms and restrictions, the conditions of operation and maintenance offered by the subjects of the goods market, as well as the quality of services is also taken into account. Having adopted the final positive decision, the II object not only can place an order, paying for it, but starts distributing positive information (messages) in social networks, contributing to the avalanche-like growth of information impact on other objects.

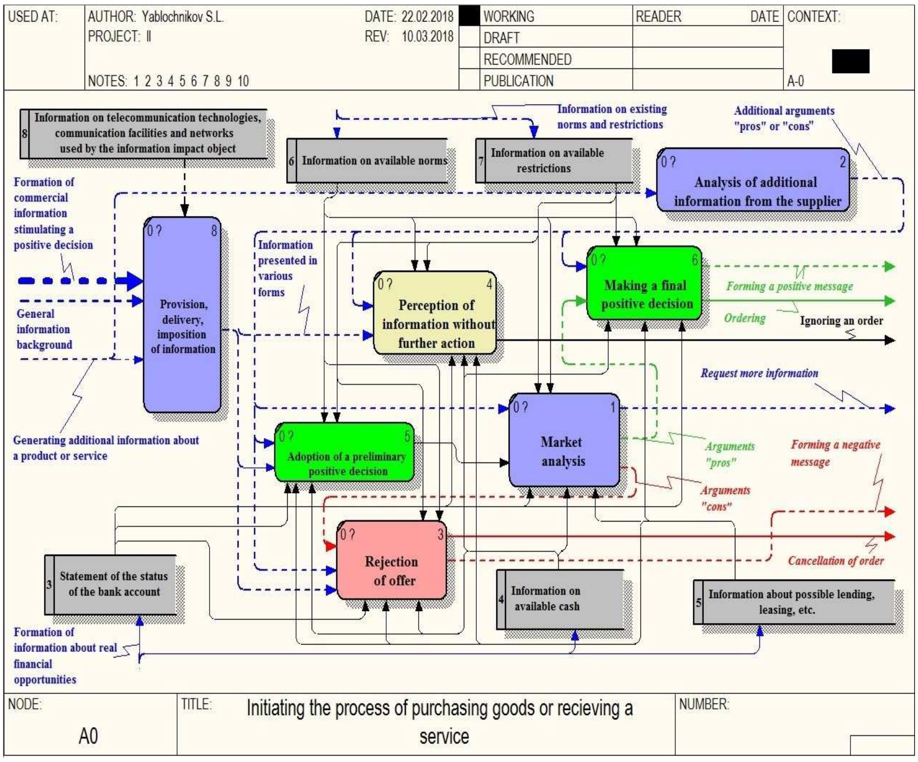

Fig. 2. DFD-diagram of stimulating the purchase of goods or services

In case of refusal of the commercial offer, the II facility can not only properly issue such a refusal, but also start disseminating negative information (negative message) among the participants of some groups of social networks regarding the attitude to the product or service formed by it, thus, in fact, carrying out elements of information confrontation. Ignoring II facilitates the transition to the so-called latent phase, however, over time, it is possible the transition to either the initial state or the adoption of one of the types of solutions (positive or negative).

Fig. 3 shows the initial DFD diagram showing the information confrontation between two competitive participants in the market for goods and servants. The processes of assessing perception, evaluating information by information impact objects, in this case, are significantly more complicated. Accordingly, the number of outcomes of the implementation of these processes also changes.

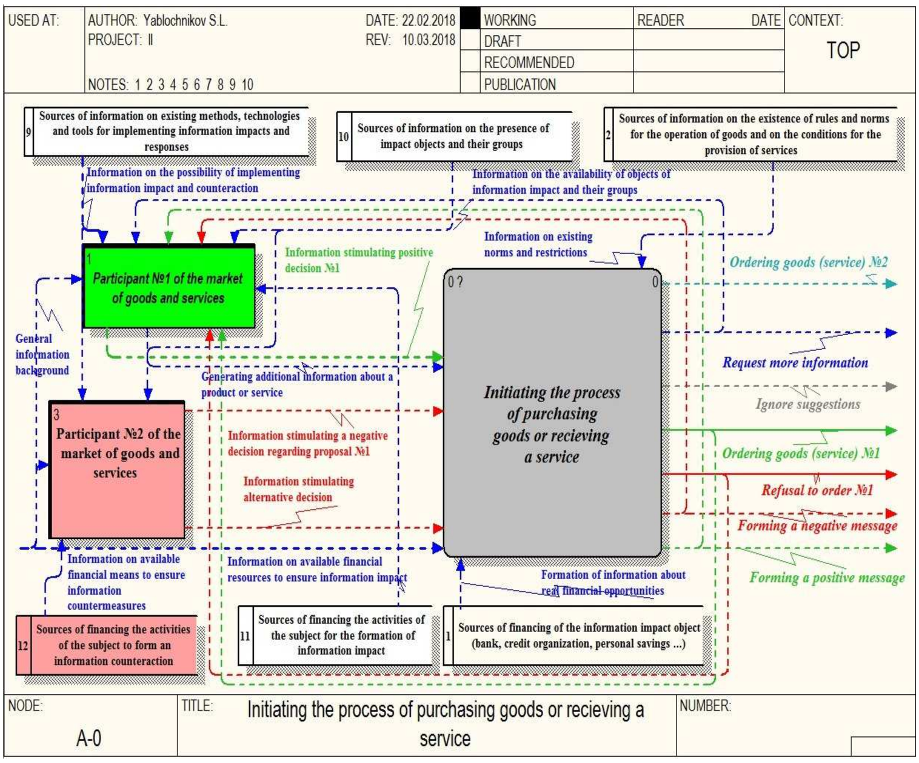

Fig. 3. Information confrontation between two market entities

In this case, there are two possible scenarios for implementing an impact on objects. The first one presupposes fair competition of the subjects, realized only through the implementation of II with information on the positive qualities of the goods and services offered, as well as on special offers, discounts, preferential terms, bonuses, warranty and post-warranty services, etc. The second is connected with the messages of one of the subjects (or both), containing obvious or implicit anti-advertising of competitors' offers.

A subsidiary DFD diagram of the implementation of information confrontation processes in the market of goods and services is shown in Fig. 4.

In this case, the object of information impact perceives and analyzes positive information about both offered goods or services. At the same time, he is being imposed negative information by one of the subjects of competition. All this becomes the basis for evaluating all the arguments "pros" and "cons", taking into account available resources and limitations. Here, for some simplification of the situation, it is accepted that only the second participant of the market applies the elements of information counteraction, and the first conducts an "honest" competition, informing the II objects only about the real characteristics of its goods (services).

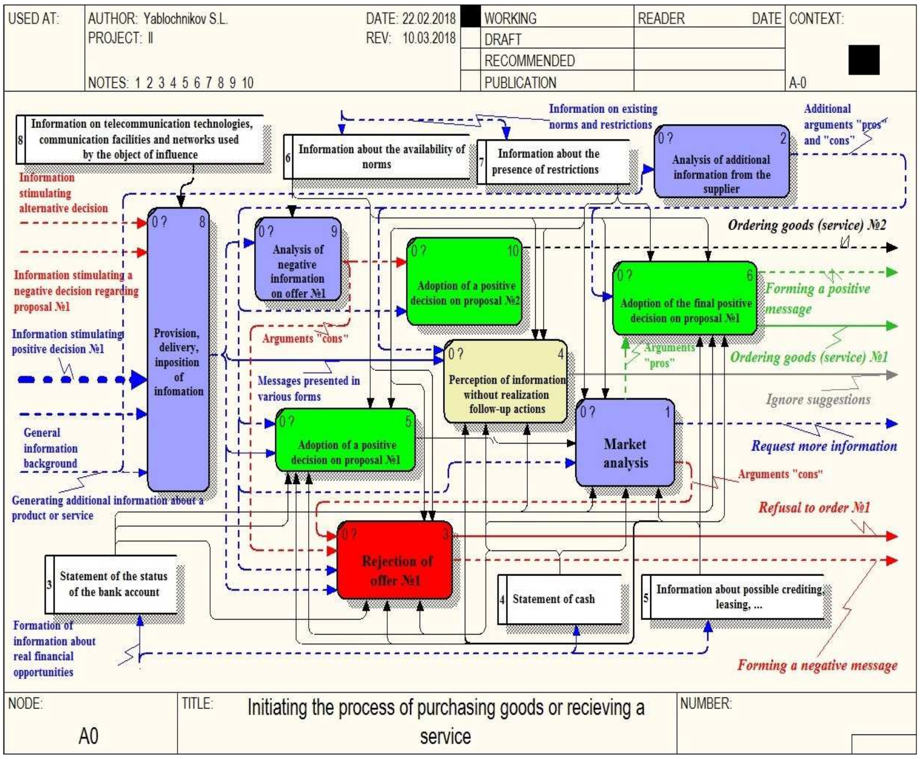

Fig. 4. Implementation of information counteraction processes in the market of goods and services

Subjects of the market, forming II on objects, legally or not quite illegally from some sources receive information about the telecommunications technologies, communication facilities, computer networks, services used by the objects of influence. This information, as a rule, is actively extracted in the global Internet, carrying out a contextual search, or by monitoring the relevant activity of potential consumers of goods and services.

5 Practical Application of the Developed Structural-Functional Models

The above principles were used by the authors of this article in practice to model the processes of promotion of telecommunications products and services in the market, and also to manage the formation of the corresponding demand. Implementation of simulation on the Anylogic platform is implemented using statistical data on the practical activities of real economic entities "Nittelekom Ltd" and "Solyaris-servis"

(Ukraine). In the experiments on actual statistical data the spreading of II from seven different users was simulated individually, as well as simultaneously from multiple sites of real social network. Depending on the typological characteristics of social groups the models of II were drawn up. The verification of the adequacy of models, their adjustment and optimization (if necessary), processing of results of simulation experiments were conducted. For the implementation of the system-dynamic models the statistics of the spreading of II in social networks was used, as well as survey data in social groups. The obtained results, firstly, made it possible to draw conclusions on the importance of applying the technology of structural-functional modeling as a preliminary stage in the formation of a hierarchical system of dynamic models in the form of a set of differential equations (1) that are interrelated and mutually conditioned. The reliability of the statistical findings mounted to 0.95. Secondly, the simulation results enabled to optimize the activity of economic objects in the sphere of promotion of goods and services in competitive environment.

6 Conclusions

The models developed by the authors make it possible to analyze and predict the dynamics of the number of objects reacting positively to II, and also to substantiate management decisions on the preparation and implementation of measures aimed at neutralizing negative impacts on the entire set of objects and their individual groups. These actions are correlated with the structure and dynamics of a complex of factors that influence such processes.

To solve the problems of researching II on groups of objects, as well as managing similar processes, it is expedient to apply structural-functional and system-dynamic modeling, which are now successfully used in the field of research of complex socio-economic processes.

The software of modern simulation platforms allows you to analyze in detail various scenarios, visually interpret the results of simulation, conduct simulation experiments. And the means of structural and functional modeling provide an effective implementation of the preparatory stages, on which the objects are identified, their possible states, realizable functions and the results achieved.

Structural and functional models of information impact and counteraction can be effectively used to synthesize the strategy and tactics of information contact, opposing structures in the economic sphere with objects and their groups, and to create sound algorithms to counteract negative information impact.

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