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MODELLING OF AVALANCHE-LIKE SOCIOECONOMIC PROCESSES

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Summary. This article is devoted to the mathematical theory of avalanche social and economic processes (currency and stock exchange panics, market agiotage), characteristic for unstable and crisis economy. The panic situations in Ukraine and Russia in 1994-2009 are investigated. Mathematical and imitating models of panic in the society of information type, differentiated under economic, social-psychological and role characteristics of subjects, are created. These models take into account the effect of synergy at interaction of subjects, the effect of purchase and loss of immunity to panic. The received models allow to reveal patterns of panic development, and then to use this knowledge in systems of preventive maintenance and suppression.

Key words: avalanche social and economic process, a panic, mathematical model of a panic, computer imitating model of a panic, preventive maintenance and suppression of a panic.

INTRODUCTION

The wide range of the socioeconomic phenomena possesses the distinctive feature uniting them in one class. Such feature is avalanche-like chain reaction, its character of expansion, development of these processes. A criterion of allocation is the structure of the environment, consisting of a set of subjects of economic relations: physical or the juridical persons co-operating among themselves, and the character of interaction based on transfer of some property from one subject to another ("in a chain"). Transfer is, first of all, the informational act as a result of which the subject-recipient gets some property or condition. This property represents presence of the accepted information and, in a certain measure, desire to execute some actions caused by it (including to transfer this information further). Such desire makes the subject an active participant of demand, supply or other kind of economic behavior. Such processes are mass processes – they develop in mass of subjects, for instance, society, where there is an interaction as chain reaction.

The following explanation will be a more accurate definition of the chosen class of processes. By avalanche socioeconomic process (ASEP) we mean the process of

distribution of some property or condition among subjects of social and economic relations through socially-psychological mechanisms of infection, imitation, suggestion, leading to a sharp change of an economic situation or environment (supply and demand, ways or methods of management) in a certain market segment. The specified mechanism of distribution – infection, suggestion, imitation – in aggregate with plural character of interaction of subjects (the quantity of communications of the subject usually is more than one) leads to chain with a branching process of formation of active subjects that has full analogy with a chain branching reactions opened by N.N.Semenov. Characterising them, chemists and physicists often apply the terms "avalanche", "fast", "explosive". The specified processes are the ones of the fastest in the system of social and economic relations. The gradation of speeds is various, most widely such terms are used (as strengthening): a concern, an agiotage, a panic. Time characteristics of speed are different for each considered process. In the context of the given work expression "avalanche process" and "fast process" are identical. At the same time, the concept of fast process is wider. The processes of catastrophic, spasmodic character also correspond to it.

The given definition of ASEP, expanded by the phenomenological description, quite unequivocally allocates a circle of considered processes. By character of development avalanche processes are similar and can be described by identical mathematical models, which defines their association with one class.

Avalanche processes seriously influence socioeconomic and political safety of the state and society, especially in the conditions of a wide spread of information-telecommunication technologies and the effect of the globalisation.

From here the importance of the ASEP prediction and management follows. The forecast of their development assumes the presence of adequate models, management is understood as preventive maintenance possibility, and at occurrence – suppression or transfer possibility into a safe (not avalanche) channel. Though the majority of avalanche social and economic processes are destructive, nevertheless, being under control, many of them have a constructive, desirable character. The question, first of all, is about distribution of high technologies, ways of manufacture and management, including new information technologies. Subjects of managing are interested in avalanche coverage of consumers by advertising, which is profitable for them (the subjects).

RESEARCH OBJECT

The stock exchange, bank, currency panics, market agiotage, creation and collapse of financial pyramids are related to ASEP phenomena. The currency and depositary agiotage of the period of presidential elections in Ukraine 2004 (fig. 1), "a salt panic", swept in February 2006 in several regions of Russia serve as examples. These are destructive avalanche processes. The distribution of fashion, new goods and technologies, including administrative ones, are constructive processes.

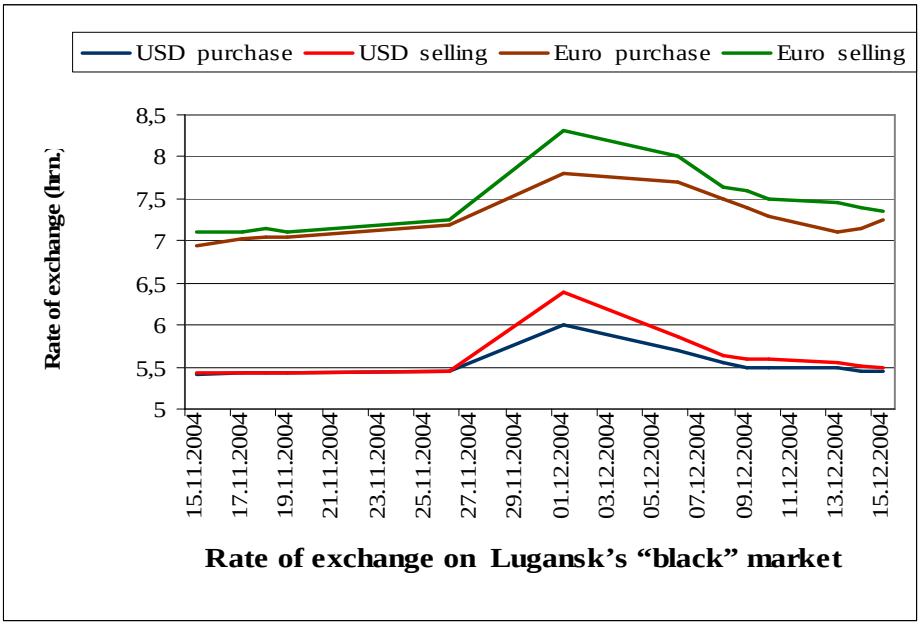

Fig. 1. The exchange rate at the "black" market of Lugansk in November-December, 2004

Processes in socioeconomic systems represent closely bound ball of the objective and subjective beginnings, communications and consequences. The major factor of occurrence and development of avalanche processes is the interaction of demand, supply and price. Disbalance of demand and supply is the basic powerful motive for a price change, and its change, in its turn, affects supply and demand. This disbalance can have both objective, and subjective reasons. The change of commodity weight volume, consumers' incomes, the prices for the given and interfaced goods, the goods-substitutes, resources, change of buyers and manufacturers quantities concern objective reasons. The given changes can be caused by other reasons and factors, the strongest – system making – transformation of economic system, change in structure of economic relations or their filling, a discount rate of national bank, taxation and social insurance system. The major objective factors concern: the national economy condition (a phase of its development), gross domestic product volume, the rate of unemployment, emission policy of the national bank, an external payment position, the political situation developing in the country and the world, and many other things.

Tastes, reasons, desires, consumers and manufacturers expectations concern the subjective factors. They can be deliberate, moreover, planned (stock exchange, currency gamble), and subconscious, often inspired (by advertising or gambling organizers) or caused by imitation (for instance, in fashion). It is important to underscore, that the subjective reasons, especially from the consumer, lead in many cases to the same, mass behavioural reactions. Turning to the mass phenomenon, such reactions of subjects become the most dynamical factor of social and economic processes.

The important methodological principle of the present work – initial division, decomposition of objective and subjective factors, construction of economic dynamics models, first of all within the limits of objective factors and reasons action, with the subsequent association, synthesis of interaction of both objective, and subjective factors.

At construction of models of dynamics the laws of preservation and equation of balance of the resource and its cost are consistently used. It, in turn, provides a sight at economy and social sphere as on the system of the interconnected elements, between which or with which help the exchange or transformation of resources is carried out. Elements represent economic and social institutes: manufacturers, consumers, the market, tax, bank systems, etc. The most important resources are money and goods.

RESULTS OF RESEARCH

One of most vivid examples of ASEP is the currency panic. Its model is considered as a base for demonstration of the technique of modelling [1,2]. The topological structure (i.e. system of elements with communications-streams, fig. 2) of the economic system is also focused on the reception of the given model. The currency panic is considered in the conditions of crisis economy (and it, in turn, allows to simplify the considered topology of a macroeconomic system). For a usual condition of economy it is possible then to create models in increments concerning an equilibrium condition.

Further in this work the analysis of streams interaction is carried out and the behaviour of the exchange rate is described by the system of differential equations.

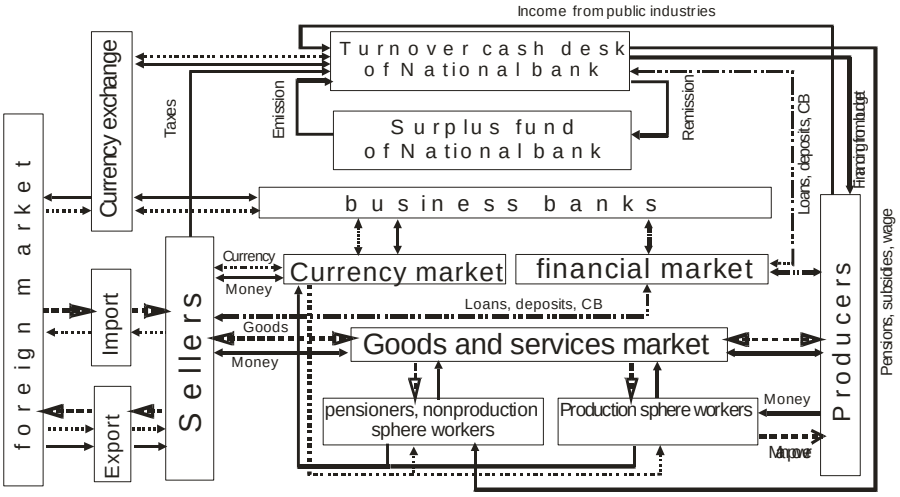

Fig. 2. Sheme of financial and goods resources movement

Let us enter some designations: $W_{in}(t, i)$, $W_{out}(t, i)$, $W_{form}(t, i)$, $W_{dis}(t, i)$ – the speed of arrival, leaving, formation, disappearance of some resource in i node; $\Phi_{ch}(t, i)$

– the speed of resource cost change at the expense of the macroreasons; $c_{in}(t, i)$, $c_{out}(t, i)$ – the unit price of quantity of an entering and leaving stream; $V(t, i)$ – the size of some resource which has been saved up in ***i*** - m node. We will designate the top indexes ***c***, ***m***, ***g*** the variables concerning currency, national money, and the goods.

In an idealized kind the situation corresponds to crisis economy, and looks as follows:

Manufacture is curtailed to zero, financing of the enterprises actually turns to the maintenance of their workers on the level with state employees and pensioners; receipts of money in turnaround cash desk of the National Bank from tax bearers and from state enterprises are not present; financing of state enterprises, salary payment, pensions, grants is carried out at the expense of issue; *consumers* (workers, pensioners) have no spare money, all issue money from them gets through a commodity market and services to *sellers of the goods*; export will curtail to zero, there is only an import for which *sellers of the goods* - *buyers of import* pay currency; in the currency market two generalised subjects operate: *banks of commerce* and *sellers of the goods*, the former are selling, and the latter are buying currency.

The currency course change defines the market. The motive power of this change is the supply and demand difference, not at local, but at global level. Let banks have exposed at the market some part $k(t,7)$ of currency reserve, i.e., $k(t,7)\cdot V^c(t,7)$, $0 \le k(t,7) \le 1$; the sellers of the goods have exposed a part $k(t,5)$ of the money stock, i.e. $k(t,5)\cdot V^m(t,5)$, $0 \le k(t,5) \le 1$ (5 and 7 – indexes of nodes "sellers of the goods" and "banks" in the scheme). Then "the potential difference", change in price motive power, will be equal $k(t,5)\cdot V^m(t,5) - c^c(t,7)\cdot k(t,7)\cdot V^c(t,7)$. The currency course change is characterised by function $\Phi_{ch}(t,7) = k_{total}(t)\cdot[k(t,5)\cdot V^m(t,5) - c^c(t,7)\cdot k(t,7)\cdot V^c(t,7)]$.

$k_{total}(t)$ – Some parametre-function defined by experiment.

As a result two systems are received. One of them describes the exchange rate:

$$\frac{dc^c(t,7)}{dt} = k_{total}(t)\cdot[k(t,5)\cdot\frac{V^m(t,5)}{V^c(t,7)} - c^c(t,7)\cdot k(t,7)], \qquad (1)$$

$$\frac{dV^c(t,7)}{dt} = -W^c_{out}(t,7); \qquad (2)$$

$$\frac{dV^m(t,5)}{dt} = W^m_{form}(t,1) - c^c(t,7)\cdot W^c_{out}(t,7). \qquad (3)$$

Another – the commodity stream and the price for the goods:

$$\frac{dV^g(t,5)}{dt} = \frac{W^c_{out}(t,7)}{c^{g,c}_{in}(t,5)} - \frac{W^m_{form}(t,1)}{r_5\cdot c^c(t,7)\cdot c^{g,c}_{in}(t,5)}, \qquad (4)$$

$$c_{out}^{g}(t,5) = r_5 \cdot c_{in}^{g,c}(t,5) \cdot c^{c}(t,7),\ r_5 > 1.$$

Function $W_{out}^{c}(t,7)$ which represents the speed of the currency stream from banks, is equaled either to the supply, or demand, more precisely, to a minimum from these two sizes, i.e.

$$W_{out}^{c}(t,7) = \min\left\{ k(t,7) \cdot V^{c}(t,7), \frac{k(t,5) \cdot V^{m}(t,5)}{c^{c}(t,7)} \right\}. \qquad (5)$$

In crisis situations the first member is usually the minimum in this pair. But the excessive demand for currency and dump of national money can lead after a while to a reverse situation.

Modelling of subjective character of interaction demand-supply is possible through parametres ***k (t, 7)*** i ***k (t, 5)***, they are the driving elements. The change of ***k (t, 7)*** is the strategy and tactics of currency traders. ***k (t, 5)*** displays behaviour of currency consumers. In a usual situation ***k (t, 5)*** <<1, because money of subjects circulates inside the country. In a crisis situation these subjects can create an agiotage, and even a panic. Further various models of a panic are considered.

They are based on assumptions, that quantity ***N*** money owners is great, the sum of their free money is identical. We accept, that the panic is spread by everyone who wishes to change their free money for currency (we will name them "infected"), transmitting this desire to *r* subjects. Values $\boldsymbol{k(t)} = \frac{\boldsymbol{I(t)}}{\boldsymbol{N}}$ (an infected part) and $k(t,5)$ also are connected among themselves. Modelling $\boldsymbol{k(t)}$ for various scenarios of infection, recovery and preventive maintenance in the conditions of various factors action (differenced society under economic, socially-psychological and role characteristics of subjects, a synergy of communicators interaction, presence of constructive and destructive mass media, acquisition and loss of immunity to a panic), we will receive a spectrum of the models reflecting specificity of environment and mechanisms of panic distribution.

The approach of Kermak and MacKendrik to modelling of epidemics (so-called SIR-model) is known [3, 4]. In the given work it is transferred from a phenomenological basis on laws of preservation and the balance equations language, and further is used for panics modelling. Representation of subjects interaction through probabilities of infection with a panic, recovery, preventive maintenance is the major element distinguishing the present work. Socially-psychological mechanisms of an individual (subject) panic, their transformation into a society panic are considered and formalized. The phenomenon of an individual panic is defined as the fast process characterised by construction of an inadequate subjective picture of the world, harmful influence (both information, and physical) on a society and on itself. Subject transition in a panic condition is not a determined, completely predicted event. Indeterminacy of such transition carries both indistinct, and stochastic, casual character. It is natural to express this indeterminacy in some value which for convenience we will name probability. It depends on psychological characteristics of the subject, situation character to which it gets, and also on influence and interaction of information sources.

In an information society each subject tests on itself the action of several information sources which, in certain cases, represent themselves as provokers of a panic, which "infect" with a panic. The synergy of such action is shown in growth of infection probability above the size defined by independent influence, i.e. above, then $pn = 1-(1-p_1)(1-p_2)...(1-p_n)$ where p_i is probability of infection from i-th source.

Society panic is the same type of correlated and mutual reinforcing actions of the mass of the subjects, caused by the social reasons and representing avalanche uncontrollable process with harmful consequences both for the whole society, and for its subjects.

Using socially-psychological mechanisms, it is possible to define basic elements, structure and properties of formal society panic models. The most widespread classes of models: the mathematical and computer imitating. The formal side of modelling consists in the following.

Let the separate subject is influenced by communicators with the various economic, socially-psychological and role signs, healthy and panicking with various level and type of influence (fig. 2).

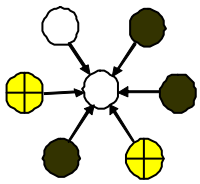

Fig. 3 Scheme of influence contacting the healthy

By circles ○, ●, ⊕ are designated accordingly - healthy, panicking (infectors) and healers.

Let us designate through A_i the event, consisting in infection of the recipient from i-th source for lack of others communicators (infectors or healers). $p(A_i)$ - probability of such event. $A = \sum_{i=1}^{n1} A_i$ - the event consisting in infection of the recipient at simultaneous action of several infectors in absence of the healers.

Through B_j we will designate the event consisting in recovery of panicking subject at the expense of j-th healer influence for lack of others communicators. $B = \sum_{j=1}^{n2} B_j$ - the event consisting in recovery of panicking by the of influence of several healers in absence of infectors.

Let now both infectors, and healers influence simultaneously. It is possible to prevent infection by reducing sensitivity to infection σ or total influence of infectors, i.e. probability of infection. For a start we will consider action only with two communicators: infector and healer. The probability of infection in this case represents probability of event $A \cdot \overline{B}$. Can the events, entering this expression, be interdependent? Not clearly. The supervision shows that more often interaction is shown in one-role groups (either infectors, or healers). Let us consider what will turn out if we accept that they are independent. In this case:

$$p_{\text{inf}} = p\left(A \cdot \overline{B}\right) = p(A) \cdot p\left(\overline{B}\right) = p(A) \cdot \left(1 - p(B)\right). \quad (6)$$

The sense of this formula explains the following reasoning. If the quantity of susceptible subjects, contacting with given infectors, equals M , then $p(A) \cdot M$ will be infected by them, after that with the influence of healer on these panicking subjects $p(B) \cdot p(A) \cdot M$ will be recover, hence, $\left(1 - p(B)\right) \cdot p(A) \cdot M$ remains infected.

If we assume the dependence of infector and healer interaction, then

$$p_{\text{inf}} = p\left(A \cdot \overline{B}\right) = p(A) \cdot p\left(\overline{B} \mid A\right). \quad (7)$$

Through $p\left(\overline{B} \mid A\right)$ the conditional probability of event $\overline{B}$ is designated. In this case deeper consideration of the interaction mechanism of communicators with various role signs, and also their interaction and influence on the recipient is required. In the given work we will be limited to independence of communicators' interaction.

Under action of several infectors and healers the probability of infection of the recipient is equal to:

$$p_{\text{inf}} = p\left(A \cdot \overline{B}\right) = p(A) \cdot p\left(\overline{B}\right) = \left[1 - p\left(\overline{A}\right)\right] \cdot p\left(\overline{B}\right) = \left[1 - p\left(\prod_{i=1}^{n1} \overline{A}_i\right)\right] \cdot p\left(\prod_{j=1}^{n2} \overline{B}_j\right). \quad (8)$$

In case of the intra-group synergy absence in operation of both infectors, and healers, the formula takes a form:

$$p_{\text{inf}} = \left[1 - \prod_{i=1}^{n1} \left(1 - p\left(A_i\right)\right)\right] \cdot \prod_{j=1}^{n2} \left(1 - p\left(B_j\right)\right). \quad (9)$$

At the same time, the intra-group synergy is commonplace and, as a rule, is present in the influence mechanism on the subject and its perceptions. In this work the formula of infection probability in the conditions of an influence synergy infectors is received:

$$p_{\text{inf}} = 1 - \mu^{\frac{k(k-1)}{2}} \cdot \prod_{i=1}^{k} \left(1 - p\left(A_i\right)\right), \quad (10)$$

Where: $k = n \quad n \le i_0$, otherwise $k = i_0$. $0 < \mu < 1$ The multiplier before composition well reflects a phenomenon of a reduction of probability uninfection under synergy influence of several infectors in the conditions of noncriticality subject

perception. Restriction of quantity influencing infectors by value i_0 is connected with a phenomenon of saturation of the recipient by the information (the often repeated information on already known theme, as well as its carriers, the recipient does not perceive).

The similar formula can be offered for recovery probability by a set of healers:

$p_{heal} = 1 - \nu^{\frac{l(l-1)}{2}} \cdot \prod_{j=1}^{l} (1 - p(B_j))$ $0 < \nu < 1$ Naturally

$p_{unheal} = \nu^{\frac{l(l-1)}{2}} \cdot \prod_{j=1}^{l} (1 - p(B_j))$. Using formulas for p_{inf} and, p_{unheal} we will receive the formula for the p_{inf} in conditions of influence of both healers, and infectors:

$$p_{\inf} = \left[1 - \mu^{\frac{k(k-1)}{2}} \cdot \prod_{i=1}^{k} (1 - p(A_i))\right] \cdot \nu^{\frac{l(l-1)}{2}} \cdot \prod_{j=1}^{l} (1 - p(B_j)), \quad (11)$$

Where: k and l are limited by some values i_0 and j_0 accordingly.

This formula is the basis for reception of mathematical models of a panic in the society, differentiated by economic, socially-psychological and role structure of participants.

Let us adduce one of such models. Its discrete variant looks like:

$$\begin{cases} S(i+1) - S(i) = -[p_{îçë}(i) + p_{ïçë}(i)]S(i) \\ I(i+1) - I(i) = [p_{îçë}(i) \cdot S(i) - p_{ëâ÷}(i) \cdot I(i)] \\ R(i+1) - R(i) = [p_{ïçë}(i) \cdot S(i) + p_{ëâ÷}(i) \cdot I(i)] \end{cases}, \quad (12)$$

Continuous (system of differential equations):

$$\begin{cases} \frac{dS}{dt} = -[p_{îçë} + p_{ïçë}] \cdot S \\ \frac{dI}{dt} = p_{îçë} \cdot S - p_{ëâ÷} \cdot I \\ \frac{dR}{dt} = [p_{ïçë} \cdot S + p_{ëâ÷} \cdot I] \end{cases}. \quad (13)$$

S, I, R - Quantity susceptible to a panic, captured by a panic and unreceptive (immunized). Their sum is equal ***N*.** And, both the first, and the second is more convenient to realize variants concerning shares in S, I, R society. The given systems are nonlinear, as probabilities p depend on unknown parameters S, I, R.

Along with mathematical, computer imitating models of distribution of a panic are constructed. Their basis is the cellular probabilistic automatic machine [5-8]. The subject of society is compared to a cell. It can be in the same conditions, carry out the

same roles, as the subject. Probabilities of transition of a cell condition from one to another, depending on the chosen mechanism of interaction, are defined by formulas like (6) – (11). Imitating models allow receiving not average pictures and indicators of development of a panic that approximates the result of modelling to real scenarios of process. In fig. 4 - 6 the elements of imitating model are shown: windows with characteristics of the subject, and the results of model work.

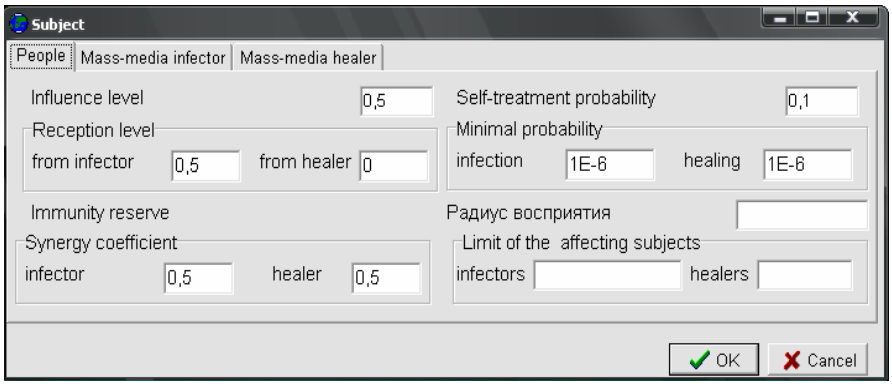

Fig. 4. A window with characteristics of the subject

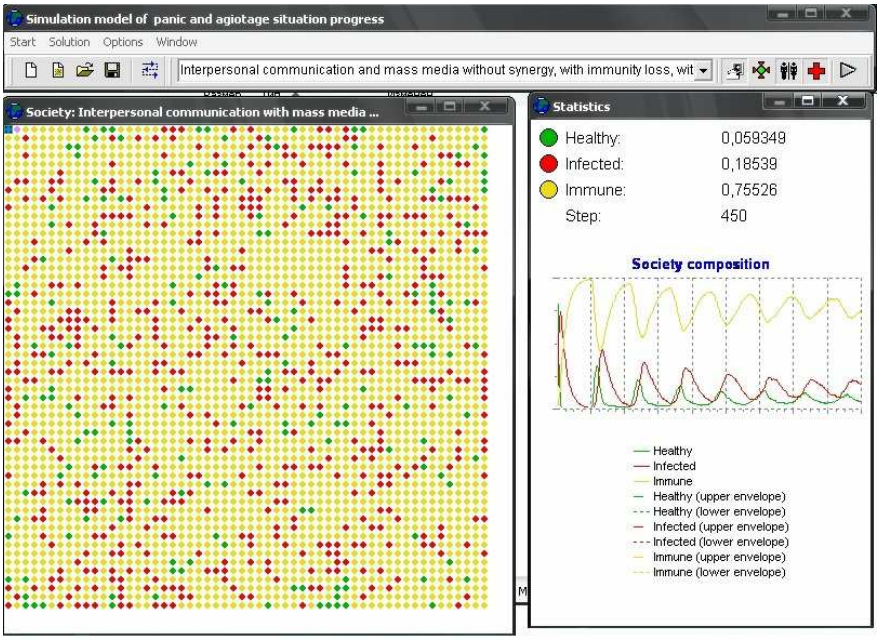

Fig. 5. An example of an intermediate configuration of society

Fig. 6. A window with data about dynamics of society in a mode of contact infection with immunity loss after certain time after recover.

CONCLUSIONS

As a result of research economic and socially-psychological mechanisms of occurrence and development of avalanche processes in SES are revealed, systematised, generalised and formalized; the modelling methodology of the basic macroeconomic indicators' dynamics, which taking into account occurrence of mass panics and an agiotage, is offered; mathematical models (system of the differential equations) of rates of exchange dynamics in the crisis conditions, which take into account the occurrence of mass panics and an agiotage, are developed. The mathematical theory of avalanche-like mass social processes of infection type (panic and an agiotage) in an information society is created; in particular:

formulas of infection, improvement, preventive maintenance in the conditions of action of various factors (society, differentiated by economic, socio-psychological and role characteristics of subjects, the synergy interaction of communicators, presence of constructive and destructive mass-media) probabilities are received; methods of reception of mathematical models and models of distribution of a panic in society in discrete and continuous forms (in the form of systems deferred and the differential equations) for various scenarios of infection, recovery and preventive maintenance in the conditions of various factors' action (society, differentiated by economic, socio-psychological and role characteristics of subjects, a synergy of communicators' interaction, presence of constructive and destructive mass-media, acquisition and loss of immunity to a panic) are developed; the interrelation of chaotic modes of development

panics in society with immunity loss by subjects occurrence is established; The fact of occurrence of the long waves similar to waves of Kondratyev is elicited, their interrelation with loss of immunity to a panic by subjects is established; as a result of the conducted natural experiments real socially-psychological and role characteristics of separate kinds of society, dynamic characteristics of processes in them (levels of a susceptibility and influence, probability of infection, quantity of contacts, roles distribution, dispersal and relaxation times;) are received.

Imitating models of a panic distribution are constructed, within the limits of the multiagent systems concept on the basis of cellular automatic machines their new kinds are created, allowing to model dynamics differentiated by economic, socio-psychological and role characteristics of society subjects for various scenarios of infection, recovery and preventive maintenance;

The established reasons, economic and socially-psychological mechanisms of occurrence and development of avalanche processes in SES allow choosing more soundly strategy and tactics of social and economic development, approaching more carefully an estimation of possible consequences of political actions, allow to create and effectively use system of decision-making support for administrative structures of various levels. The developed methodology of dynamics models construction of the basic macroeconomic indicators, which take into account the occurrence of mass panics and an agiotage, the received models allow to find out development mechanisms of currency, exchange, commodity panics and then to use them in preventive maintenance and suppression systems.

Results of work are in detail described in [1,2], presented on sites of the East Ukrainian Volodymyr Dahl National University (http://www.snu.edu.ua/index.php?mode=305) and of the Institute of technology (s. Severodonetsk) (http://www.sti.lg.ua/page.php? pageid=93).

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МОДЕЛИРОВАНИЕ ЛАВИНООБРАЗНЫХ СОЦИАЛЬНО-ЭКОНОМИЧЕСКИХ ПРОЦЕССОВ

Данич В.Н.

Аннотация. Статья посвящена математической теории лавинообразных социально-экономических процессов (валютных и биржевых паник, рыночного ажиотажа), характерных для неустойчивых и кризисных экономик. Исследованы панические ситуации в Украине и России в 1994-2009 гг. Созданы математические и имитационные модели паники в обществе информационного типа, дифференцированном по экономическим, социально-психологическим и ролевым характеристикам субъектов. Эти модели учитывают эффект синергии при взаимодействии субъектов, эффект приобретения и потери иммунитета к панике. Полеченные модели позволяют выявить сценарии развития паник, и затем использовать эти знания в системах профилактики и подавления.

Ключевые слова: лавинообразный социально-экономический процесс, паника, математическая модель паники, компьютерная имитационная модель паники, профилактика и подавление паники.