183 ТЕХНОЛОГІЯ ЗАХИСТУ НАВКОЛИШНЬОГО СЕРЕДОВИЩА

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MODELS OF EVENT RISKS FROM THE POINT OF VIEW OF SYSTEM'S ENTROPY

The work is devoted to the analysis of the possibilities of entropy mechanisms for factorization and control over risks in different systems. Proposed was the model for predicting event risks from the point of view of their energy and information supply. Such a risk assessment model allows you to get rid of the shortcoming's characteristic of probabilistic and statistical methods of assessment. Risks are derived from some sequence of predicted events. The most acceptable indicators of such systems are energy and related thermodynamic regularities, as well as information that obeys similar laws. The model is based on dynamic characteristics of the event row in their time and entropy dependence that allow to predict and control real risks for particular systems within infinitely small time period of transition from chaotic uncertainty to a certain risk forming event. Indices of ordering-disordering of relative values of specific flows of entropy of events, taken into account on the basis of interpolation of the existing data bases for particular systems were taken as the criteria for risk generating events. Graphical interpretation of the model has the view of an oriented graph in multi-layer time parameters «event-cause-and-effect link» and its matrix representation. The presented technique is nothing more than a method of forecasting a certain and narrow in content class of phenomena, in particular, it refers to risks. The method of risk analysis, based on event series in a certain time interval close to the present time, allows you to assess the risk itself in the indicators of the system, understandable to the user and comparable with the indicators of other systems.
Key words: *risk, events, risk formation, entropy, time scale, events scale, prediction, matrix, uncertainty, oriented graph of events.*

Волошин В.С. Моделі подійних ризиків з точки зору ентропії системи. *Робота присвячена аналізу можливостей ентропійних механізмів факторізації та контролю ризиків у різних системах. Запропоновано модель прогнозування ризиків подій з точки зору їх енерго- та інформаційного забезпечення. Така модель оцінки ризику дозволяє позбутися недоліків, характерних для імовірнісного та статистичного методів оцінки. Ризики випливають із певної послідовності передбачуваних подій. Найбільш прийнятними показниками таких систем є енергія і пов'язані з ними термодинамічні закономірності, а також інформація, що підкоряється подібним законам. Модель базується на динамічних характеристиках ряду подій у їх залежності від часу та ентропії, що дозволяє прогнозувати та контролювати реальні ризики для окремих систем за нескінченно малий проміжок часу переходу від хаотичної невизначеності до певної події, що формує ризик. За критерії ризикогенеруючих подій було взято показники впорядкованості-невпорядкованості відносних значень питомих потоків ентропії подій, що враховані на основі інтерполяції існуючих баз даних для окремих систем. Графічна інтерпретація моделі має вигляд орієнтованого графа за багатошаровими параметрами часу «подія-причинно-наслідковий зв'язок» та його матричне представлення. Представлена методика є не що інше, як метод*

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прогнозування певного та вузького за змістом класу явищ, які, зокрема, відноситься до ризиків. Метод аналізу ризику, заснований на рядах подій у певному інтервалі часу, близькому до теперішнього часу, дозволяє оцінити сам ризик за показниками системи, зрозумілими користувачеві та порівнянними з показниками інших систем.
Ключові слова: *ризик, події, формування ризику, ентропія, часовий масштаб, масштаб подій, передбачення, матриця, невизначеність, орієнтований граф подій.*

Description of the problem. The fact that risks, existing in various systems are determined by numerous applied parameters, depending upon the designation of the system brings topicality for the problem of rational unification of such parameters so that there should be possible to carry out a comparative analysis of the notion of «risk» itself for such systems topical. Taking into the account that risks are derivatives of a certain sequence of forecasted events it is quite logical to assume that for such system energy and thermodynamic regularities connected with it and information, which governed by the same regularities appear to be most applicable indices. It is quite possible to admit admissible to that there may be some other universal parameters of the system that may be correlated with notion of risk. Such indices will become unified if we manage to find some general regularities, allowing to unite the sense filling of the notion of «risk» and energy-information content of the systems for which this analysis is carried out.

The analysis of recent research and publications. Time, events, system's entropy, its risks, all these indices can be inter-related and have their own sense positions regarding the subject of this work and the sense of the notion of risk [1]. Let us try to show just in the first approximation the inter-relations of the notion of «event risk» with the process of entropy in the systems on the basis of the generally known. It is quite obvious that entropy, as a measure of energy (information) dissipation is an index of system's dynamism. The smaller is this set and fixed in time dissipation measure the more is the degree of the system's orientation on consecutive structuring and revelation of new system qualities, opposing to appearance of uncertainty. And vice versa, the greater is energy (information) dissipation the greater are the system's efforts to gain stability, equilibrium or steadiness. These indices possess, as a rule, a dual interpretation. For example, the stability of the system with maximal entropy and the stability of the system with minimal growth of this index differ in their relation to the processes of development. The first one loses its capabilities of self-development. Quite the opposite the second one is exceedingly informative and possesses opportunities of redistribution of energy or information within the system and outside, so that some new qualities properties, previously not peculiar to it could spring up in it. The same is appropriate for such system's index like risk, connected with its existence and efficient operation. The same is appropriate for such system's index like risk, connected with its existence and efficient operation. Nominally, in $R = \psi(\Delta S)$ coordinates inter-related characteristics risk and entropy are met for the first time. Their main quality lies in ultimate uncertainty of this dependence. So far, in literature there no objective publications, dedicated to this subject, while the question of inter-communication between risk and entropy was analyzed only with application of generalized terms [2-5]. It is necessary to understand that not only time with its solely directed «arrow», as a universal index, present in such coordinate scale could be the governing coordinate for them, but also a consecutive scale of anticipated, realized and already occurred events [1]. Transitional processes for such events, preceding the present time, can be represented as indices of the system's risk. Particularly, the notion of bifurcation as the area of transition from stability to unstable state and vice versa, or a point of the system's transition from uncertainty to a certain quite determined state and vice versa, can be related to the alternation of the parameter of the state of the system's risk in «0;1» binary code. So, it is quite appropriate to maintain that such properties of the system should be determinative for the notion of «event risk».

Purpose of the article. The objective of the work is to investigate the inter-links between even risks and changes of entropy in the systems of risk generation, as well as creation of efficient models of risk control on the basis of criteria of entropy.

Presentation of the main material. In a simplified variant an increase of entropy of the system ΔS is a quantitative measure of a disordered state, which is determined by the number of admissible events (C), related to the system as $\Delta S \cong k \ln C$. The entropy of the system is bigger, when there are more admissible variants of its states, predicted from the future and the events, related to them, that

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determine these states preceding the present. So, for the future time the number of undetermined eventful states is $C_Б >> 1$, while for the present time there is only one quite certain risk-generating eventful state $C_H = 1$, which is happening at the moment. The transition from $C_Б >> 1$ to a quite certain, determined $C_H = 1$ is carried out within an infinitely small-time interval $\delta\tau \to 0$, preceding the present, which was described in [1]. That is why the condition $\Delta S_Б >> \Delta S_H$ (Fig. 1) is always observed. So, the risk of receiving from the future a certain determined event at transition from risky uncertainty to a quite certain event of the present always correspond to the following scripture $R \cong (\Delta S_Б - \Delta S_H) / \Delta S_Б \to 1$. Such calculations can lead to the fact that the state of the system for which $R > 1$ can become a reality. However, it is against the logics of the theory of probability (see Fig.1) and can be confirmed by the following argumentation regarding the functions of interrelation of energy-entropy of certain determined events and related to the systems risks.

Particularly:

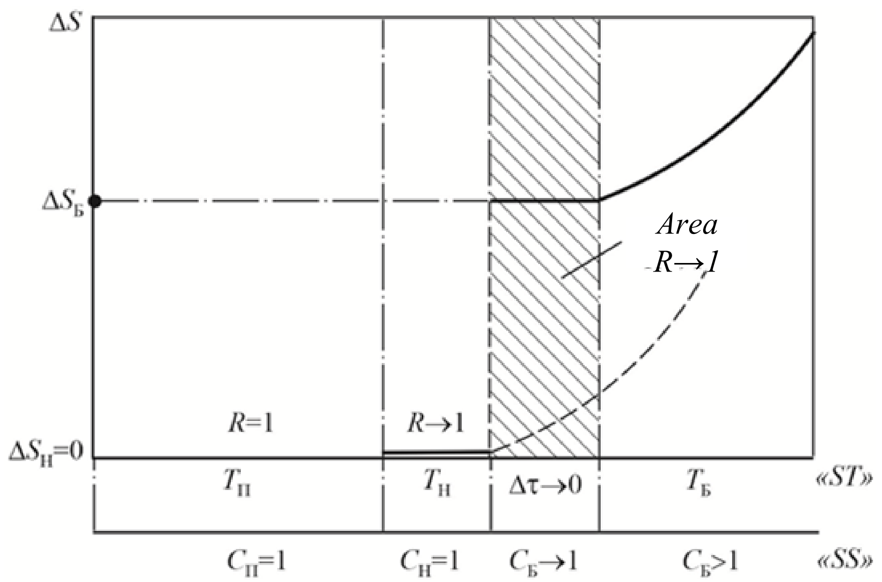

Fig.1 – Assumed entropy of risk within relations of time «ST» and eventful «SS» of measurements

For a certain system, which is in the state of weak nonequilibrium within an infinitely small time interval $\delta\tau$, a thermodynamic flow J_j, characterizing the velocity of a particular event j, depends on thermodynamic forces x_j, characterizing the potential of this event and determine the sequence and functioning of other events or processes communicating with event j. The function of dissipation (scattering) for such event is connected with this parameter by means of L. Onsager's phenomenological dependence: $\sigma = \sum_{j=1}^{n} B_j J_j x_j$ for weak nervous systems [1]. In our case this function serves, also, as a function of exchange of entropy between inter-related and consecutive in time events within an infinitely small-time interval $\delta\tau$ [1].

The value of changes in entropy may show the degree of the order of the system, in which some sequence of inter-related events is going on. According to L. Brilluen the degree of Y order is determined by the difference between the highest $\Delta_e S_{\max}$ and the current $\Delta_e S$ values of entropy in energy exchange between the events and the environment. The degree of the order of X system is determined as the difference between the current $\Delta_e S$ and the minimal $\Delta_e S_{\min}$ values of entropy of such exchange.

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$$Y(\tau) = \Delta_e S_{\max} - \Delta_e S(\tau);$$
$$X(\tau) = \Delta_e S(\tau) - \Delta_e S_{\min}$$

The degree of ordering and disordering are linked with polysemantic parameters of the original system and, as a rule cannot be very closely compared. In this case [7] it is required to pass to relative indices of evaluation of the degree of the system's ordering, like, for instance, correlated with X and Y indices in time and related to the general scale of changes of entropy $\Delta_e S_{\max} - \Delta_e S_{\min} = \Delta$. Then, the relative value for the indices of ordering and disordering at observation of the obvious condition $K_Y + K_X = 1$ may acquire this view:

$$K_X = (\frac{\Delta_e S(\tau)}{\delta\tau} - \frac{\Delta_e S_{\min}}{\delta\tau}) / \frac{\Delta}{\delta\tau}.$$

The main parameter here is a relative value of alternation of the local specific stream, participating in exchange processes of the system with its environment at different time periods.

The methods applied in this investigation presume determination of 10 arbitrarily chosen, but ordered and inter-related events for monitoring and predicting most risk forming from them, with periodicity once in every 5 days, for consecutive 100 days. For each chain of events a relative value of changes of local specific flow of entropy is calculated for the specified period of time, also measured is the minimal range and the values of K_Y and K_X indices are calculated. Indices with a growth of the relative value of changes in entropy towards growth the value of the index of order decreases and vice versa. It should be noted that alternation of the relative value of the local specific flow of entropy for a particular chain of events has got a vivid non-stationary character and depends upon a multitude for reasons that may seem casual at first glance. In fact, the chains of events are inter-related with cause-and-effect relations of their own, it making them more recognizable and evaluation of entropy for each of them becomes quite predictable.

This model can be easily represented in the form of a consecutive oriented graph (see Fig. 2), where the tops (qj) are reflection of some anticipated events (j) or the occurred «00» event at each *i-th* level of the predicted time interval in future in relation to present, while the graph's ribs denote cause-and-effect connections, that *consecutively* transform one *j-th* reason into another, functionally comparable with it. Represented here are four consecutive time levels ($q = 4$) of anticipated events, each of them being independent from other events of equal levels.

Own inter-level connection appears only at transition to the next time level.

Let us detach three components:

– anticipated events (four levels within time interval of future in Figure 2);

– event interval between potential and realized events ($\delta\tau \to 0$);

– he area of already realized events and the present time T_H.

The lowest, first level of events shows us exactly the bifurcation, for instance, in the form of a catastrophe during assembling, when within the time period $\delta\tau$ just three not determined so far variants of events 11, 12, 13 remain and only one of them, particularly event 12 is the one which has already occurred in time instant $\delta\tau$ in the present time (see fig. 2). The chain of anticipated events, that led to the realized «00» risk possesses the following view:

$$00 \leftarrow \overbrace{(12)}^{I} \leftarrow \overbrace{(23)}^{II} \leftarrow \overbrace{(34)}^{III} \leftarrow \overbrace{(34 \to 36)}^{III} \leftarrow \overbrace{(44 \to 46 \to 48 \to 49)}^{IV}$$

All other remaining events did not lead to the real result, «00» event in this case.

Such graph (see Fig. 2) is formed in methodical sense by the matrix-chronological definition of cause-and –effect interactions for a certain event and the conditions for its occurrence that can alter the sequence of events in an arbitrary way, thus bringing a high degree of uncertainty into the method.

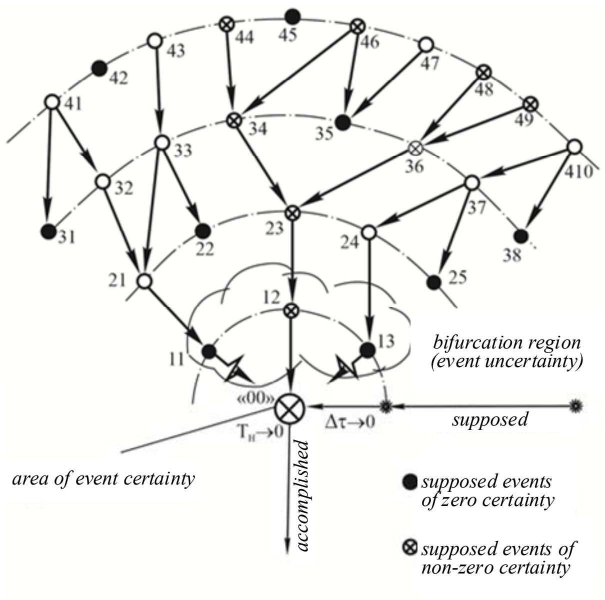

Fig. 2 – Oriented graph of reflections of presumed events and cause-and-effect connections [$J(j=1,1,J) \to Q(q=1,1,Q)$] between the events, being in supposition to some equal conditions

Cause-and-effect interactions of event processes can be easily traced at every specific (*i-th)* one-moment matrix mode (see Fig. 3), in the form of elements of a_{jk} matrix, where j – being the number of the reason of occuring of the event, k – is the number of the consequence, which is the base of the event. As follows from the Table (see Fig. 3) a certain marker can be attributed to each cause-and-effect connection, consisting of ones and zeroes and reflecting correspondence of this event to some conditions.

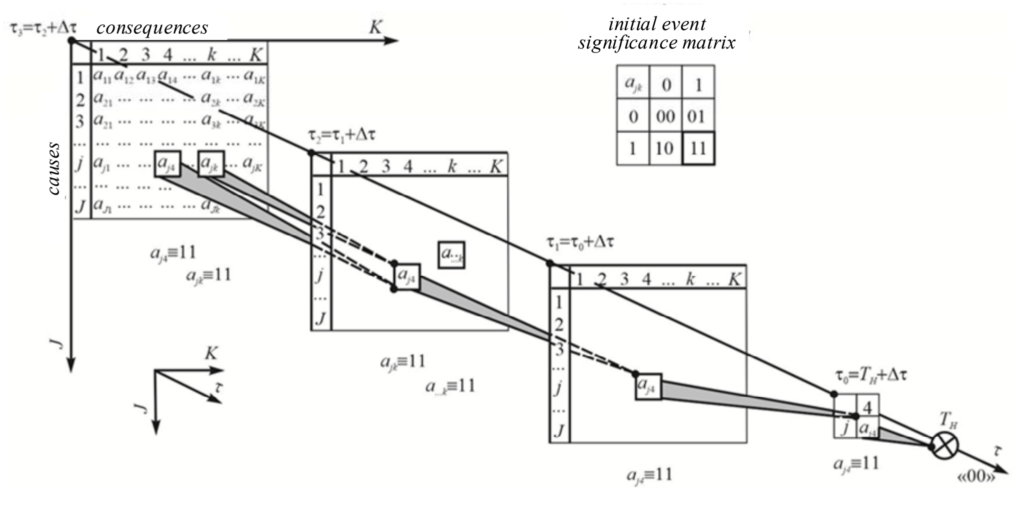

Fig. 3 – Dynamic matrixes of cause-and-effect links for evaluation of a real risky event «00» within some time interval

The size of matrix element can be different. For instance, if elements of the matrix of correspondence are derivatives of experts' evaluations, it means that they can represent the essence or numerical experts' evaluations. The essence of the matrix for some value of $\tau_i = const$ remains fully preserved at that, because there is a time component, dividing the content of each matrix element in its own i-*th* time interval τ_i. It brings some shape of universality for such scriptures. In the long run, such matrix gives

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an idea regarding a singular event, which is bound to become real from anticipated future through time interval, for instance, $3\Delta\tau$. Within this time interval a risky event $a_{j,4}$ will come true as actually realized from all possible $a_{jk} - th$ events.

Now, let's go back to Fig. 1. The structural hierarchy of events, described here presumes that at each event row, for each anticipated event there is specific own entropy $\Delta_{p,q}S(\tau)$, where p (0,1,4), q (1,1,10), determined according to Shannon's law and calculated depending upon the amount of information, which is connected with a specific sequence of inter-related events within some time interval. The calculated values of K_Y and K_X indices within some time interval, written for comfort, by parametric dependence $\tau^* = 100 - \tau$, so that the relations of differently oriented scales «ST» and «SS», represented in Fig. 4 should be observed. The opposite directions of the time arrow and entropy on the one hand and the scale of events, on the other hand, are stressed by their main properties described above. For the time arrow and entropy, it is consecution and inevitability of occurring of the next time, subsequent dissipation of energy or information. For the scale of events, it is uncertainty and palliative character of the states, which are yet to come. Thus, the dynamism of the events consecution is a derivative of the dynamics of the system's entropy and is determined by this parameter

The dynamics of the relative value of changes of entropy of separate events (see Fig. 2) from chaotic to the ordered state can be traced, particularly, by the following $44 \to \cdots \to 23 \to 12 \to "00"$ and leads to a singular unambiguous event «00», possessing the properties of objective risk. The detached value of the index or the order at that is $K_Y = 0,62$. In this relation there was another chain of predicted events $410 \to 24 \to 13$, but it, like all other chains, pictured in Fig. 2 did not lead to a real risk formation, due to obviously unstable value of K_Y coefficient. Other eventful connections have not been digitalized here due to the figure's density, but can be traced by the reader by comparing Fig. 2 and Fig. 4. The general conclusion can be that entropy as a measure of order or disorder in event information can represent a presumable variant of cause-and-effect relations between the events that precede formation of a real risk.

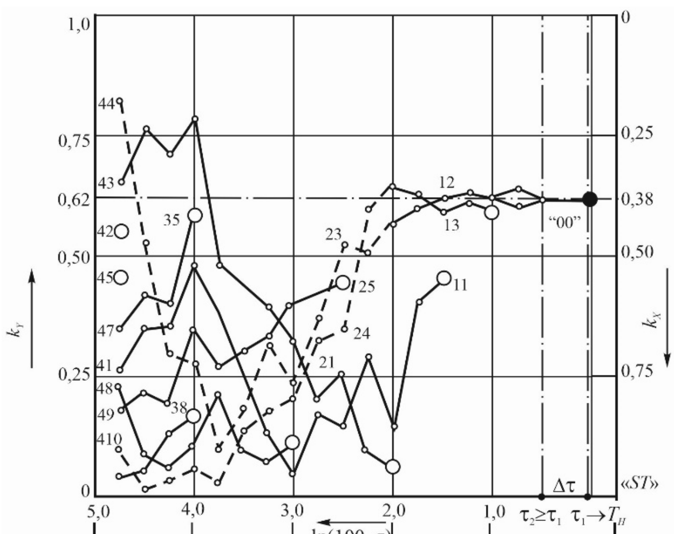

Fig. 4 – Interaction and inter-relations in the dynamics of changed indices of entropy regulating within the scales of time – «ST» and events – «SS» respectively

The insurmountable difference is in the fact that future is unpredictable and present is quite certain. Unavailability of the predicted is one of the postulates of nature, on the basis of it there appears understanding of uncertainty of future and the risk, corresponding to it. Only practice of the accomplished in the form of «accumulated capacity of events» that have already occurred, its investigation, its extrapolation on future uncertainties can serve as a criterion, it being verified by practical application of the described.

Conclusions

In fact, the represented methodic is but the method of predicting a certain class of phenomena which is rather narrow in its content. In our case it's a time sequence of events, possessing energy and information of their own that lead to risk generating results. The evaluation of such events is done on the basis of determination the measure of energy o information dissipation, individual for each of predicted events. The represented method of analyzing of risk, on the basis of event rows within some time interval, approximated to the present time makes it possible to evaluate the risk in the system's indices, which are understandable for a user and comparable with indices of other systems.

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