Criteria for sustainable development of the system through risk assessment

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Abstract. Based on modern developments in risk theory, it is proposed to identify two objectives of system risk management: the first (strategic) goal is focused on ensuring (maintaining) sustainable development of the system; the second (current) goal involves keeping the amount of risk within acceptable limits for the functioning of the system. Regarding the diagnosis of the activity of a particular object of study, the concept of stability can be used to characterize the stability of its position in an unstable environment. There are two areas of stability assessment: the stability of the environment and the stability of the system. Based on the considered properties of the beta coefficient, it is proposed to use the modified formulas of this indicator for diagnostics of stability and diagnostics of development within the mechanism of risk diagnostics of different levels of management. These formulas can be used for estimation of separate indicators, groups of risk factors, or risks of the object at whole. Evaluation of indicators in accordance with a certain diagnostic criterion takes into account the dynamics of values, therefore, the authors considers the calculation of the chain growth rate of indicators in index form for the relevant (identical) periods of time as the best option for standardization.

1. Introduction
A mandatory element of risk management is the diagnostics of the object of management and, accordingly, the choice of research criteria. The object of management is a certain system (political, economic, environmental, energy, territorial, etc.). The criterion of risk of the object of diagnostics is considered a characteristic or the sum of characteristics, on the basis of which it can be concluded whether the risk of deterioration of the object of the study or not. Such a criterion should not only state the presence of risk, but also assess its level. If the value of the criterion only makes it possible to determine the risk, then the subjectivity of the assessment will be inevitable. It is desirable to obtain a quantitative assessment of the level of risk using such indicators that are used in planning, accounting and analysis of the system, which is a necessary condition for the practical use of this assessment.

Most contemporary Ukrainian and foreign scientists consider two groups of risk assessment methods: quantitative or objective (mathematical, statistical and probabilistic, analytical) and qualitative or subjective (modeling, optimization and game theory, methods of stochastic programming, analogues) [1-5].

Quantitative methods involve risk assessment in absolute and relative terms. In absolute terms, the risk is measured by denominate values – the frequency or size of possible losses in monetary terms. In relative terms, the risk is measured by various dimensionless indicators, which is the ratio of two or more denominate values. For practical application, it is recommended to use several types of risk
assessment with the choice of the most acceptable option. Quantitative assessment methods are to some extent unified, but they cannot always be used to assess any type of risk in all possible situations (lack of time, information, qualifications). There are types of risks that require a fundamentally individual approach to their assessment, as well as there are complex risks, the elements of which are several types of risks. That is why, along with universal, specific risk assessment methods are used. But none of these methods provides a clear recommendation for the choice of research criteria, risk diagnostics and, accordingly, introduces additional subjective aspects into the risk management process.

2. Methods. Review of Literature

An important point in the management of a particular system is the transition from risk management to the management of the object of study, taking into account risk factors and the choice of key diagnostic criteria for the implementation of all system management processes. I. O. Blank [6, p.220] considers the factors influencing the choice of specific methods of risk assessment. Having analyzed them, it is possible to formulate basic factors of a choice of methods of diagnostics of system taking into account risk: type of risk; completeness and reliability of the information base formed to assess the levels of probability of different types of risks; the level of qualification of managers (risk managers) who perform the assessment; the degree of their readiness to use the modern mathematical and statistical apparatus of evaluation; hardware and software for managers (risk managers), the ability to use modern computer technology assessment; the possibility of involving qualified experts in the assessment of complex types of risks.

For systems operating in an unstable environment (political, economic, environmental, etc.), a realistic concept of risk diagnostics cannot in principle be based on the classical principles of static probability, which provide for the possibility of unlimited repetition of the same events in the same initial conditions. In this regard, to measure the risk in the activities of such systems special measurement tools should be used – special scales, indicators, algorithms.

At the same time, the scope of using the simplest linear indicators, such as mathematical expectations, is narrowing, because in the conditions of abrupt changes in the dependency environment that more or less adequately reflect reality, they rarely satisfy the simplest relations represented by linear models that are built on efficiency indicators. Not only the form of a certain dependence becomes unstable, but also the composition of factors influencing a given phenomenon or process, or state of activity. This is especially true of risk factors in an unstable market economy.

G. B. Kleiner, W. L. Tambovtsev, R. M. Kachalov [7, p.200] cite the following differences of the modern approach to risk assessment of the enterprise as a system: rejection of a priori proposals about stochasticity (randomness) of the studied processes and quantities; use of the concept of risk, only when its outcome is significant to the subject (risk assessment is a subjective category). Researchers who are directly involved in risk management note that qualitative methods should perform only a complementary function. Therefore, the search for relatively simple and at the same time reliable quantitative methods of risk diagnostics is ongoing. It is only occasionally possible to separate out a single criterion for evaluating a single event or operation. As for the system, it is characterized by a certain composition of its elements (subsystems, relationships between them, subordination and mutual penetration, etc.) and, accordingly, a large set of factors that shape its state at a given time and further affect the positive or negative (in terms of subject) changes. As a result, different evaluation criteria can be used at individual levels of government, the combination of which forms a certain vector-function of parameters, consisting of all or part of the partial criteria. But the application of any model (including risk diagnostics) is almost much simplified by the possibility of forming a single assessment criterion (key risk indicator).

A key risk indicator is an indicator that, in accordance with the established criteria for assessing the state of the system, takes a defining position on the purpose, prospects and strategy of system development in the direction of qualitative improvement of its functioning. Its establishment is important in connection with the definition of targets necessary for the formation of a strategy for the
development of the system in the future. Thus, the key risk indicator is a set of parameters for changing the state of the risk object (research system), which most likely reflects the change in the risk profile of the system and allows diagnosing the necessary management decisions to improve (restore) the risk object. Such parameters are the statistical values of various indicators, which can be used to determine the sensitivity of the system (object of study) to the impact of risk. These indicators are determined on the basis of periodic data, usually annual, less quarterly or monthly. They should provide an opportunity to assess the impact of various risk factors on the functioning of the system (external and internal, financial and environmental, etc.).

3. The Results

Research into ways and means of using a key risk indicator in operational risk management was initiated by Risk Business and the Risk Management Association in collaboration with many (over 50) global financial companies. In the future, this work was to be brought to practical application at various enterprises (more details on this can be found in the article of N. L. Ivashchuk [8]).

When choosing methods of integrated assessment it is necessary to take into account the following points: the structure of the elements of this assessment cannot be constant, because it depends on the goals and objectives of the study; in order to form a single criterion, it is necessary to periodically review the priorities and organize them with the help of clearly defined rules. Properly formulated diagnostic criteria should most fully characterize the essence of risk as a category and be the same for all levels (subsystems). Quantitative certainty and content of the criterion are reflected in specific indicators of risk assessment. Forming a system of indicators, it is advisable to adhere to the following principles: ensuring an organic relationship between the criterion and the system of specific indicators; reflect the use of all types of resources; the possibility of applying indicators to the management of various subsystems; performance of indicators of stimulating function in the course of use of available reserves of growth of efficiency of activity.

Based on modern developments in risk theory, we propose to identify two goals of system management, taking into account risk factors. The first (strategic) goal is to ensure (maintain) the sustainable development of the system. The state of operation of the system, focused only on minimizing risks, ensures the stability of the facility at the current time, but leads to deterioration of this state in the future as a result of lags in technical, technological, organizational and other aspects due to the risk of untapped opportunities. Sustainable development implies a steady trend towards improving performance indicators. The second (current) goal is to keep the magnitude of the risk within acceptable limits for the object of study (limits). The boundaries of risk are objective and subjective, determined by many factors and can be of different types: legal, restrictive decisions of a particular risk entity, the timing of transactions (events).

All systems at a certain level of research (except global) are open, the internal stability of which largely depends on the conditions, features and trends of the external environment. Therefore, it is especially important to study the problem of sustainability, stability of the system, which are a kind of indicators of the effectiveness of adaptation mechanisms in conditions of uncertainty of the external environment, and hence overcoming risks. The works of Ukrainian and foreign authors on management consider different approaches to the analysis and assessment of stability. For example, within the theory of economic risk (A. Marshall, 20-30 years of XX century. [9]) it was found that companies operating in conditions of uncertainty, should be guided in their activities by two criteria: the size of the expected profit and the size of its possible fluctuations. According to this theory, a stable profit is more useful than a profit of the same expected size, but with significant fluctuations in its level.

The problem of stability was dealt with by prominent mathematicians and mechanics: A. M. Lyapunov, J. La Salle, I. G. Malkin, A. Poincare, J. Lagrange, M. E. Zhukovsky, V.V. Rumyantsev et al [10-15]. As a starting point for the concept of stability in relation to the state of equilibrium of a dynamic system, we can use the definition of A.M. Lyapunova. According to its concept, the equilibrium state will be stable if for any given region of permissible deviations from the
equilibrium state (region $\varepsilon$) it is possible to specify such a region $\delta$ (including the equilibrium state), with the trajectory of any motion that began in the region $\delta$, will never reach the boundary of the region $\varepsilon$ [10].

In the 90s, considerable attention of scientists was paid to the ecological and social components of stability (sustainability) of the operating environment. The research was based on identifying the internal causes of environmental conflicts and eliminating them through the use of levers of economic influence on the behavior of nature users.

Regarding the diagnostics of the functioning of the system, the concept of stability can be used to characterize the stability of its position in an unstable environment. There are two areas of stability assessment: the stability of the environment and the stability of the system (object). The stability of the system is a state of its individual elements and subsystems, such is its dynamics, which provides a consistently high result of the system. Achieving sustainability is based on the principle of actively responding to changes in internal and external factors. The stability of the environment is considered in the context of its stability, the deterministic action of factors that determine the basic characteristics of its state. External, for example, in relation to the enterprise stability is determined primarily by the stability of the economic environment (direct and indirect influence), within which the enterprise operates: it is achieved by appropriate mechanisms for managing a market economy in the economic system as a whole. The stability of the system can be considered as a compensatory mechanism that allows it to adapt to the destabilizing effects of both internal and external environment in the process of achieving its goal.

Thus, sustainable development is a constant, stable process by which there is a transition from the lowest quality state of the object to the highest. It is logical to use the term "development" instead of "growth" due to the fact that there is a "limit to growth" and there are no limits to "development". After all, growth is understood as a quantitative increase in an object or indicator, which, of course, has its limits, and development includes other components - the quality of the process or object, its rating, etc., i.e. something that has no limit. It is necessary to note another connection between risk and sustainability. It is known that stability is due to two polar trends, one of which is associated with the reproduction and preservation of "old" system qualities (system-forming, or in other words "negative"), while the second, on the contrary, provides a "positive" ability to adapt to "New" conditions, changes in the environment. For example, a company with a high level of risk (one that pursues an active innovation, investment policy) provides a high "positive" stability. A low-risk enterprise (which adheres to the so-called "conservative" innovation and investment policy) provides high "negative" stability.

Therefore, the risk diagnostics of the system should consider both management objectives, taking into account risk factors, namely the sustainability of development and limited impact. This allows us to identify three areas of risk diagnostics, the implementation of which at different levels of the study is shown in Figure 1.

![Figure 1. Implementation of areas of risk diagnostics at different levels](image-url)

Based on the level of management (including diagnostics) and based on the study of the state of functioning of the lowest level system, we can distinguish respectively internal (micro-) and external
(mega-, macro- and meso-) stability. Risk assessment at the mega and macro levels is usually performed using qualitative or combined methods with extensive use of expert assessment. Leading firms of different countries on the basis of extensive use of quantitative indicators of the country's development and expert assessments have developed their own, fairly reliable, methods of assessing mega- and brand risks. Among the most well-known are the methodology of the German insurance company Euler Hermes [16], the scheme of risk factors of the Swiss Banking Corporation [17], the BERI index [18], the methodology of Euromoney magazine [19], the competitiveness rating of the Swiss International Institute for Management Development, the Control Risks Group (CGS) [20], the Institutional Investor (II) Bank of American World Information Services, Nation Westminster Bank, rating methodology Standard & Poor's Rating Group (S&P), etc.). Most of them assess mega- and macro-risks by analyzing the following components: political, economic and financial risk, and then rank countries according to the overall assessment of this risk.

Within the framework of our research, the main attention will be paid to the diagnostics of meso- and micro-risks, which directly affect the activity of the lowest level systems, are generated by them and must be constantly regulated by the control system. Thus, we will form a theoretical and methodological basis for the diagnostics of the system taking into account the risk: the risk of the system is considered as an equivalent complex of its individual types; the set of risks of the system is divided into compatible (those in which probable adverse situations can be realized simultaneously) and incompatible (those in which probable adverse situations are mutually exclusive); risks are considered as equal risk factors that determine them at the same level of research; risks are considered as accumulated risk factors that determine them at different levels of the hierarchy; assessment of the degree of influence of individual risk factors on the state of the object of risk is carried out by assessing the stability, growth, sensitivity to change; consideration of each subsequent risk factor (at the highest level of integration) is performed on the basis of previous factors according to known rules, each subsequent indication (risk factor) specifies the integrated risk assessment; the risks of one level of diagnostics are combined by addition (aggregation) as the arithmetic mean or weighted average; total (aggregate) risk is determined by the accumulation of risks at the levels of the hierarchy - by calculating the product or geometric mean, depending on the accepted evaluation system.

Our study shows that to date there is no generally accepted list of estimated risk indicators. In our opinion, the system of initial measures-indicators of risk should be formed on the basis of the following methodological principles: adequacy of the system of indicators to the tasks of diagnostic research, i.e. the ability to identify and assess the impact of a certain group of risk factors); availability and accessibility of information support for empirical research; the presence of a sufficient number of research periods to form a certain trend of changes in the values of the indicator (all periods must be the same); the possibility of accumulating a statistical base on the level and dynamics of change of indicators, which is an information prerequisite for the development of rating models for risk diagnostics; quantitative measurability; the ability to clearly define algorithms for calculating indicators; high degree of variability and relative awareness, clear and unambiguous definition of negative or positive impact on the level of risk of the object of study; the optimal number of indicators from each area of research, the exclusion of duplicate indicators.

The basic criterion for diagnosing the resistance of the object of study to risk, we determined the \( \beta \)-coefficient, by analogy with the known indicator of systematic risk, proposed by W. Sharp [21, 22]. To calculate it, we use the classical calculation formula:

\[
\beta_j^c = \frac{\sum_i (T_{ij} - \bar{T}_j) \cdot (T_{im} - \bar{T}_m)}{\sigma_j^2 \cdot m},
\]

where \( \beta_j^c \) - the criterion of sustainability of the j-th object of study (for example, a separate area compared to the ecological system of the country or the ecosystem of the settlement compared to the ecosystem of the region as a whole when assessing environmental risks of different levels of aggregation);
\( T_{ij}, T_{iu} \) – growth rate of the indicator for the j-th object (subsystem) and growth rate as a whole for the system of the highest level in the i-th period (ecosystem of the world, countries, territories as a whole, etc.);
\( \overline{T}_j, \overline{T}_s \) – the average growth rate for the j-th object of the study and for the system as a whole for the period m;
\( \sigma_s^2 \) – variance in growth rates for the system as a whole for the period m.

As a result of calculations, we obtain that the \( \beta \)-coefficient of a certain investigated factor for the system as a whole will be one. For facilities (individual countries, regions, settlements) with a more stable position (smaller deviations of growth rates from the average level than the whole), the value of the \( \beta \)-coefficient will be less than one, which will indicate a more stable operation of the facility and, accordingly, less risk. According to the classical theory, there is no risk if there are no changes.

The next stage of calculations is the task of diagnosing the development of the object (country, region, etc.), because one stability in dynamic conditions of change is not enough. Each object (system and its separate components) should develop, improve characteristics of the condition, that is be characterized by positive tendencies of change of an estimation indicator.

In order to ensure the information unidirectionality of indicators, they are divided into stimulants and disincentives. For stimulants, higher values are considered better, and for destimulants - on the contrary, lower. In practice, the indicators involved in various studies can be divided into three groups: explicit stimulants - indicators that under most conditions of use play a positive role, i.e. a higher value of the indicator corresponds to a better score; explicit disincentives - in most cases have a negative impact on the object of study, i.e. it is better to have a lower value of the indicator and, accordingly, the tendency to decrease; stimulants-disincentives - the impact of the indicator is assessed depending on the purpose of the study and the subject of management - in some cases, a positive increase in the value of the indicator, in others - vice versa.

To further enable the aggregation of criteria for the diagnostics of stability and developmental diagnostics, disincentives must be converted into stimulants. Since, at the previous stage, all initial indicators were converted into growth rates in the index form, the presence of positive dynamics will be evidenced by the excess of growth rates relative to the level of growth rate of the system as a whole for stimulants. For disincentives, on the contrary, a decrease in growth rates will be positive.

Therefore, depending on the direction of the initial evaluation indicators, we will use the following formulas to diagnose development (growth). For stimulants:

\[
\beta_{ij}^p = \frac{\sum_{m=1}^{n} [(\overline{T}_j - T^p) \cdot I_{ij} \cdot \Delta T_{iu}]}{\sigma_s^2 \sum_{m=1}^{n} I_{ij}},
\]

(2)

where \( \beta_{ij}^p \)-criterion of development (growth of values) of the j-th object of research;
\( T^p \) – average for the studied system as a whole rate of development, which respectively depends on the positive or negative dynamics of the system as a whole and is calculated:

\[
T^p = \begin{cases} 
\overline{T}_s, & \text{if } \overline{T}_s > 1, \\
1, & \text{if } \overline{T}_s < 1;
\end{cases}
\]

(3)

\( I_{ij} \) – indicator of adverse deviations on the j-th object of study in the i-th period, which is determined by:
\[ I_{ij} = \begin{cases} 0, & \text{if } (T_{ij} - T^*) > 0, \\ 1, & \text{if } (T_{ij} - T^*) < 0; \end{cases} \]  

(4)

\[ \Delta T_{ij} = \begin{cases} (T_{ij} - T^*), & \text{if } (T_{ij} - T^*) < 0, \\ \sum_{i=1}^{m} |(T_{ij} - T^*)| \cdot I_{ij}^{-}, & \text{if } (T_{ij} - T^*) > 0; \\ \sum_{i=1}^{m} I_{ij}^{-}, & \text{if } (T_{ij} - T^*) = 0; \end{cases} \]  

(5)

\[ \sigma^2_{\Delta} \]  

- variance on adverse deviations of growth rates in the system as a whole for the period \( m \) (calculated by the standard formula, where the values of the indicator are replaced by deviations, in this case negative).

Similar transformations are carried out for destimulators.

To calculate the level of risk generated by a particular partial factor under study, the aggregate indicator is defined as the arithmetic mean or weighted average of the criteria of stability and development. This allows you to take into account the effect of both components of meso-risks. In fact, the arithmetic mean is a special case of the weighted average, provided that the weights of both criteria are the same. Then the general formula has the form for estimating the \( k \)-th indicator is:

\[ \beta_{jk} = \beta_{jk}^p \cdot q^p_k + \beta_{jk}^c \cdot q^c_k, \]  

(6)

where \( \beta_{jk} \) - aggregate level of risk on the \( j \)-th object for the \( k \)-th indicator (the subject of management depending on the level of detail of the analysis of separate components of concrete risk factors can apply one or several indicators for research);

\( q^c_k, q^p_k \) - respectively weights – the importance, significance of stability or growth for the \( k \)-th indicator \( q^c_k + q^p_k = 1 \) (usually determined by the expert method).

Given the same significance in assessing the state of the object of study of constancy and growth of the indicator, the weights are 0.5 and, accordingly, the aggregate indicator is defined as the arithmetic mean. The effect of a single factor can usually be investigated using several interrelated indicators. But the subject is not interested in the influence of a single partial indicator, but a certain factor, a group of factors on the state of the object of study (for example, a separate region for meso-risks). That is, the next task is to assess the aggregate level of risk of a particular factor.

If the defining property of the population (a set of indicators selected to assess the effect of a particular risk factor) is formed from individual values of the feature (partial indicators), the theory of statistics recommends the use of geometric mean. The advantage of geometric mean over arithmetic is that it avoids the possibility of not taking into account significant deviations in the level of risk through averaging. From the point of view of the concept of sustainability, there is less risk in an object with all the average characteristics than in an object that is characterized by different levels of influence of risk factors (both positive and negative).

Subject to the accumulation of simultaneous action of a certain risk factor at different levels of research ("a certain type of pollution at the national level" \( \rightarrow \) "pollution at the level of a separate territory" \( \rightarrow \) "pollution at the level of a separate settlement" \( \rightarrow \) etc.) the risk level of this factor will be defined as values at selected levels of research (or the weighted average of the systematic risk for a given object at the \( v \)-th levels of research and the actual risk of a particular object as the last level of management - the share can be determined by adjusting \( 1 / v \) to the coefficient of determination).
The analysis of the obtained results, comparison of the level of risk for a specific object by selected risk factors or for different homogeneous objects (countries, sectors of the economy, regions, enterprises) is quite convenient to build a risk profile (Fig. 2).

According to the level of investment development, there are three types of activity (agriculture, hunting and forestry; wholesale and retail trade, trade in vehicles, repair services; real estate transactions, leasing and services to legal entities) which are characterized by sustainable development during 2001 - 2019, the level of risk is much lower than the general market. At the same time, for two types of activity (except for real estate transactions) the determining factor is the positive dynamics of growth of fixed capital investment. For two activities (industry, hotels and restaurants) is characterized by a level of risk close to the market. Other objects of assessment have a rather high degree of risk. Characteristically, it is possible to observe for most major activities similar values of both risk criteria (stability and development) for this research factor. A similar risk profile (Fig. 2) can be constructed for one object of study, then the level of risk will be plotted on the axis generated by individual factors, which will clearly highlight the critical factors and focus on them when developing measures to improve the condition of the object of study.

4. Discussions and Conclusions
The results obtained in the diagnostics of stability and the development of meso-risks for different objects is quite simple to evaluate according to the procedures of the rating method. In this case, the normative value for the level of risk is - $\beta$-coefficient equal to one. Thus, the rating method allows you to rank the objects of study (countries, regions, settlements, segments of activity) by individual indicators, factors, groups of factors. The main disadvantage of rating and normative methods is the problem of choosing a standard for comparison, the need for its differentiation for different objects and constant updating. This leads to limitations on conclusions about the level of risk and the inability to develop universal recommendations for partial evaluation criteria. In Ukraine today, there are no organizations that would conduct a comprehensive rating assessment of various types of risk objects at the meso- and micro-levels and could provide appropriate private advice to interested clients (government or business entities). This means that customers must diagnose the risk themselves. There are two problems: informational, due to the fact that the open data required for a comprehensive diagnostics of an object is not enough; methodical, associated with the lack of adapted to the conditions of Ukraine model of evaluation of indicators, normative values of criteria, evaluation scales.

Thus, the considered mathematical procedures for the diagnostics of meso- and micro-risks are universal, have a specific practical orientation and provide ample opportunities for managers to assess the level of risk of various objects (systems): economic activities, industries (e.g., industrial activities),
subsectors, areas, city, district, enterprise, segment of activity, etc. The practical application of the proposed models primarily depends on the available statistical information, the possibility of obtaining it, the degree of reliability. The acceptability of the assessment results is largely determined by the subject's risk appetite.

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