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O.I. Shumlianska

Odessa national maritime university

FACTUAL, PROGNOSTICATED AND STANDARD
MULTIFACTOR SENSITIVITIES

О.І. Шумлянська

Одеський національний морський університет

ФАКТИЧНА, ПРОГНОЗНА І СТАНДАРТНА
БАГАТОФАКТОРНІ ЧУТЛИВОСТІ

It has been carried out the characteristics of the different conditions of occurring the factor's changes concerning the plan (project) efficiency criterion. Depending on these conditions the classification of multifactor sensitivity has been undertaken. It has been offered the multifactor index of the plan (project) criterion's sensitivity on connections with all determining factors or with factor's groups. This multifactor index embraces all kinds of sensitivity (factual, prognosticated, standard).

Keywords: criterion, factor, change, factual, prognosticated, standard, any, multifactor index of sensitivity.

Здійснена характеристика різних умов виникнення змін факторів критерію ефективності плану (проекту). Проведена класифікація за цими умовами багатофакторної чутливості критерію. Запропоновано багатофакторний показник чутливості критерію на зв'язках з усіма визначаючими факторами або їх групами. Розроблений багатофакторний показник чутливості охоплює всі види чутливості (фактичну, прогнозну, стандартну).

Ключові слова: критерій, фактор, зміна, фактичний, прогнозний, стандартний, довільний, багатофакторний показник чутливості.

Многофакторный анализ предполагает совокупное изменение всех действующих факторов или их групп, актуальных в сложившихся экономических ситуациях. Изменения факторов происходят в различных условиях, которые необходимо учитывать как при постановке задач исследования, так и при анализе их последствий. В связи с этим представляется целесообразным выделять следующие виды изменений факторов:

1. Фактические изменения факторов. В эту группу изменений $\{\Delta x_i\}$ входят заданные изменения факторов и реально образованные изменения Δx_{pi} факторов. Их можно отнести к совокупности событий, которые, возникая при выполнении плана, уже реально совершились. Фактическое изменение факторов может происходить при отсутствии взаимодействия между ними. Но может иметь место и их взаимовлияние, не всегда очевидное, но которое естественным путем интегрально и адекватно отражается в величине возникающих апостериорных изменений факторов $\{\Delta x_i\}$. В итоге, использующая эти реальные результирующие изменения $\{\Delta x_i\}$ рациональная формула системного многофакторного показателя чувствительности (МПЧ) критерия также будет адекватно учитывать взаимодействие факторов.

2. Прогнозируемые изменения факторов $\{\Delta x_{pri}\}$. Такие изменения связаны с событиями, которые могут совершиться в будущем. Прогнозируемое изменение факторов имеет место при (общем или частном) планировании (проектировании). Могут быть прогнозы дискретных изменений или прогнозы интервала изменений факторов. Прогнозирование изменений факторов может быть основано на опыте и интуиции, когда они, по сути, назначаются субъектом.

3. Стандартные изменения факторов $\{\Delta x_{ci}\}$. Представление о величине реакции критерия на всю совокупность изменений факторов в условиях значительной неопределенно-

сти, когда прогнозирование неприемлемо, можно получить, составив некоторый системный потенциал меры многофакторной чувствительности, основанный на стандартных изменениях факторов. Величины этих изменений Δx_{ci} , с учетом системного подхода, в том числе «равноправия» факторов, должны быть приняты такими, чтобы все их отношения к величинам своих факторов x_i по модулю были одинаковые.

Предложенный средний многофакторный показатель чувствительности (МПЧ) критерия эффективности плана (проекта) обобщает однофакторный показатель чувствительности, охватывает все три вида чувствительности (фактическую, прогнозную и стандартную), применим при произвольных допустимых изменениях факторов.

Ключевые слова: критерий, фактор, изменение, фактический, прогнозный, стандартный, произвольный, многофакторный показатель чувствительности.

Problem statement. The works, dedicated to the improvement of the sensitivity researches of the plan criteria towards the disturbing factors, are of big scientific and practical interest. Being in tight connection with the planning departments' activity concerning revealing and estimating plan risks (this activity is especially important in competitive environment of the market of the sea transport services), the sensitivity researches deserve special attention. The researches of the efficiency criterion's reaction towards any admissible factors' changes, occurring in different conditions and considered in integral totality, are of big interest. The solution of arising questions can be found on a way of development of the multifactor sensitivity research offered by the author.

Review of the last researches and publications. One of the basis of traditional researching such important relative characteristics of the plan as sensitivities of its efficiency criteria, determining one-factor sensitivity indexes on the connections $y(x_1, \dots, x_n)$ with the separate factors x_i ($i = 1, \dots, n$) [1; 2; 3; 4; 5; 6]. The average on the

factor's change Δx_i x_i ($i = 1, \dots, n$) indexes of sensitivity $sens(y, x_i)$ and point one-factor indexes of sensitivity $sens^*(y, x_i)$ are presented by the corresponding formulas:

$$sens(y, x_i) = \frac{y(x_1, x_2, \dots, x_{i-1}, x_i + \Delta x_i, x_{i+1}, \dots, x_n) - y(x_1, \dots, x_n)}{\frac{\Delta x_i}{x_i}}, \quad (1)$$

$$i = 1, 2, \dots, n.$$

$$sens^*(y, x_i) = \lim_{\Delta x_i \rightarrow 0} sens(y, x_i) = \frac{\partial y}{\partial x_i} \cdot \frac{y(x_1, \dots, x_n)}{x_i}; \quad (i = 1, \dots, n).$$

Then the experts analyze the calculated values of sensitivity indexes.

Along with advantages (simplicity, obviousness) the one-factor sensitivity analysis has some disadvantages [1] and the essential disadvantage is just its one-factor research as it doesn't allow taking into account the cumulative effect of the factors' changes. Besides, the considerable part of this method represents the expert analysis inevitably containing subjective conclusions.

The perspective multifactor sensitivity analysis will allow to overcome the noticed disadvantages. The works [7; 8; 9; 10] are dedicated to this problem. These works contain the formulation of the problem about the reasonability of the multifactor approach towards the multifactor sensitivity research of the effectiveness criterion and they contain determining the average multifactor index of sensitivity (MIS) in the assumption about identical-percentage factors' changes.

In the works [11; 12] the notion of the average MIS has been widened and it has been worked out the point MIS that have the differential form.

Apparently, works [7-12] contain separate results of research of the big important theme. Therefore they deserve development and representation in interrelation.

Tasks of research. The tasks of this research are:

1) the characteristic of different conditions of occurrence of the factors' changes and classification of the multifactor sensitivities of the criteria on these conditions;

2) representation of the various MIS of the efficiency criteria of the plan (project) towards any admissible changes of all factors or of group of factors in different conditions.

Basic material of research. Multifactor approach towards the criteria's sensitivity research, in comparison with one-factor sensitivity research, allows characterizing the plan's (project's) stability towards disturbance influences of the changing factors. Multifactor approach towards sensitivity and its analysis allows to research the problems of plan's (project's) stability in case of available, but not obvious, interrelation between the factors, when the one-factor sensitivity researches are not sufficient.

Multifactor analysis assumes the cumulative change of all operating factors or of their groups, actual in the developed economic situations. Changes of factors occur in various conditions which are necessary for considering both at statement of research problems, and at the analysis of their consequences. In this connection it is reasonable to allocate the following kinds of factors' changes:

1. Factual factors' changes. This group of changes $\{\Delta x_i\}$ includes the given changes of factors and really formed changes of factors Δx_{pi} . They can be carried to the totality of events which, arising at fulfilling the plan, really has taken place already. Factual change of factors can occur in the absence of interaction between them. But it can be factors' mutual influence, not always obvious, but which is integrally and adequately reflected in the quantity of arising posterior factors' changes $\{\Delta x_i\}$. As a result, using these real resultant changes $\{\Delta x_i\}$ the rational formula of the system multifactor index of sensitivity (MIS) of the criterion also will adequately consider the factors' interaction.

2. Prognosticated factors' changes $\{\Delta x_{pri}\}$. Such changes are connected with the events which can take place in the future. The prognosticated factors' change takes place at common or partial planning. There can be prognostications of the discrete factors' changes or prognostications of an interval of factors' changes. Prognosticating factors' changes can be based on experience and intuition when they, as a matter of fact, are set by the person. If the totality of factors' changes has set changes, they can be considered as prognosticated changes with the probability equal to unit. In the conditions of considerable uncertainties in factors' changes, forecasting is possible only with small probabilities of the events' realization that actually excludes forecasting application.

3. Standard factor's changes $\{\Delta x_{sti}\}$. It is possible to get a vision about the quantity of the criterion's reaction towards the whole totality of the factor's changes in conditions of considerable uncertainty, when forecasting is unacceptable, having made some system potential of a measure of the multifactor sensitivity, based on standard factor's changes. The quantities of these changes Δx_{sti} , taking into account the system approach, including factors' «equality», should be accepted such that their ratios to the factors x_i by module were identical that can be expressed by the formulas

$$\frac{\pm \Delta x_{sti}}{x_i} = \alpha = const > 0,$$

or

$$\Delta x_{sti} = \pm \alpha x_i, \quad (i \in I \subseteq \{1, \dots, n\}); \quad (2)$$

the sign of changing Δx_{sti} and set quantity α depend on the criterion's economic essence. The introduced changes Δx_{sti} of the factors (2) are named *standard* [8], and the quantity α is the module of the standard relative factor's change.

To the described different kinds of factors' changes there correspond the following kinds of the criterion's sensitivity:

1. The factual multifactor sensitivity of the criterion.
2. The prognosticated multifactor sensitivity of the criterion.
3. The standard multifactor sensitivity of the criterion.

Let's give the formulas expressing the relative characteristics of all kinds of multifactor sensitivity. Further all kinds of the factors' changes will be designated by the symbol Δx_i .

Supposing arbitrarily changed all n factors, we will note formula of MIS as generalizing the one-factor index of sensitivity (1) expressing the ratio of the relative changes of the criterion and of the factor. We will introduce the following

DEFINITION. The average multifactor index of sensitivity (MIS) of the plan criterion $y(x_1, \dots, x_n)$ towards the set of any admissible changes of all n factors $\{\Delta x_i\}$ ($i=1, \dots, n$), $sens(y, (x_1, \dots, x_n))$, is named the quotient obtained when the relative n -factor change of the criterion $\Delta y / y$ is divided by the root-mean-square relative factors' changes, represented the relative change of some reduced factor

$$sens(y, (x_1, \dots, x_n)) = \frac{y(M') - y(M)}{ny(M)} \cdot \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\frac{\Delta x_i}{x_i}\right)^2} \quad (3)$$

where

$$M(x_1, \dots, x_n)$$

and

$$M'(x_1 + \Delta x_1, \dots, x_n + \Delta x_n) \quad (4)$$

basic and replaced n -measured points.

At changing only group n_1 of factors $x_i, i \in I \subseteq \{1, \dots, n\}$, where n_1 – number of indexes in a subset I , the above introduced definition changes as follows.

DEFINITION. The average multifactor index of sensitivity (MIS) of the plan criterion $y(x_1, \dots, x_n)$ towards any admissible changes of a group n_1 of factors $x_i, i \in I \subseteq \{1, \dots, n\}$, $sens(y, (x_i, i \in I \subseteq \{1, \dots, n\}))$, is named the quotient obtained when the relative n_1 -factor change of the criterion $\Delta y / y$ is divided by the root-mean-square relative changes of n_1 factors, represented the relative change of some reduced factor:

$$sens(y, (x_i, i \in I \subseteq \{1, \dots, n\})) = \frac{y(M'_I) - y(M)}{n_1 y(M)} \cdot \sqrt{\frac{1}{n_1} \sum_{i \in I} \left(\frac{\Delta x_i}{x_i}\right)^2} \quad (5)$$

where n -measured point

$$M'_I(x_i + \Delta x_i, i \in I \subseteq \{1, \dots, n\}; x_v, v \in \{\{1, \dots, n\} \setminus I\}) \quad (6)$$

Suggested multifactor indexes of sensitivity (MIS) can be applied to the multifactor research of all three kinds of criterion's sensitivity.

The formulas (3) and (5) represent the relative quantity – ratios of the multifactor quantities, reduced to one factor. Owing to structure of multifactor indexes of sensitivity the numerical values of y and $\Delta x_i / x_i$ can be represented with different units of measure that is convenient at calculations. The formulas (3) and (5) represent the average MIS, and they are expressed through the finite (discrete) quantities' changes, and it is convenient for the practical calculations. And they also allow to calculate $sens$ when it is impossible to represent the criterion y in the form of functional dependence from factors, for example, at researching multicriteria optimising problems [5; 6].

Let's suppose that $\{\Delta x_i\}$ are standard displacements, i.e. satisfying the conditions (2). In this case the formulas of MIS (3) and

(5) are led accordingly to the following formulas of standard MIS

$$\text{sens}(y, (x_1, \dots, x_n)) = \frac{y(M^\alpha) - y(M)}{n\alpha y(M)} ; \quad (7)$$

$$\text{sens}(y, (x_i, i \in I \subseteq \{1, \dots, n\})) = \frac{y(M_I^\alpha) - y(M)}{n_1\alpha y(M)} , \quad (8)$$

where n -measured points M , M^α and M_I^α are presented by the expressions

$$M(x_i), (i = 1, \dots, n) ; M^\alpha(x_i \pm \alpha x_i), (i = 1, \dots, n) ; \\ M_I^\alpha(x_i \pm \alpha x_i; x_\nu), (i \in I \subseteq \{1, \dots, n\}; \nu \in \{\{1, \dots, n\} \setminus I\}) , \quad (9)$$

n_1 – number of factors equal to number of indexes in a subset I .

The signs «+» or «-» in (9) are the same, as well as at corresponding Δx_i in (2), and they are defined by the essence of economic process.

Conclusions

1. Suggested average MIS of the plan criteria generalizes the one-factor sensitivity index, it embraces all three kinds of sensitivity (factual, prognosticated and standard) and it is applicable at any admissible factors' changes.

2. Presented characteristic of the different conditions of the factors' changes, concerning the effectiveness criterion, clarifies the essence and abilities of the criterion's multifactor sensitivity research, that will promote increasing the efficiency of the sea transport enterprises' management decisions in conditions of changeable market environment.

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Рецензенти:

доктор економічних наук, професор, завідувач кафедри «Економічна теорія і кібернетика» Одеського національного морського університету **Г.С. Махуренко**

доктор економічних наук, старший науковий співробітник відділу ринку транспортних послуг Інституту проблем ринку та економіко-екологічних досліджень НАН України **О.А. Липинська**