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Economic-Mathematical Model for Assessing the Sensitivity of International Innovation and Investment Projects

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Abstract*: International innovation and investment activity occupy a special place in the system of modern international business. The authors propose an economic and mathematical model for assessing the sensitivity of international innovation and investment projects by the criterion of net present value. It is advised to use the obtained sensitivity indicator as an additional one in assessing the economic efficiency of international innovation and investment projects of an enterprise. The proposed model makes it possible to determine the effect of several internal parameters simultaneously on the net present value of the project.

Keywords* : Economic-Mathematical Model, Assessing the Sensitivity, Innovation, International Projects, Investment.

I. INTRODUCTION

International investment activity occupies a special place in the system of modern international business because achieving a high level of socio-economic development in the country and the world is impossible without an effective structured innovation and investment policy for the formation of international economic relations in order to create a favourable investment climate [1-3].

Investment projects on an international scale are a sophisticated type of project activity based on complementary relationships and opportunities of partners, requiring significant investments of financial resources [4-5]. The specifics of the implementation of projects that go beyond the national borders of one state lies in the differences manifested in the economic, technological, political, social spheres of the countries participating in the projects.

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In the current economic conditions, increasing the innovation and investment activity of the country, industries, enterprises is an effective tool to ensure the conditions of exit from the economic crisis, scientific and technological progress, one of the most effective mechanisms of structural transformation. The economic situation in many countries (high inflation rates, sharp fluctuations in the national currency exchange rate, the volatility of the legal base, the unstable financial condition of most enterprises) significantly complicates the implementation of innovation and investment processes. These factors have a direct impact on the requirements of the implementation of innovative investment projects and the internal parameters of the projects. Such internal parameters may be revenue, cost, product price, cash flow, profit tax rate, discount rate, and more. Therefore, it is necessary to develop and use appropriate methodological tools to evaluate the impact of these parameters, which will provide additional information on the feasibility of implementing the project to choose the best option from several alternatives.

Investing is a critical element of economic development in current business conditions. The instability of the global economy at this stage has complicated the investment process. In this regard, higher requirements are imposed on the soundness of investment investments. There is a need to improve the accuracy of calculations in the pre-investment phase [6].

II. FEATURES OF INTERNATIONAL INNOVATION AND INVESTMENT PROJECTS

The critical aspect of the investment and innovation process is the definition of its subjects. The concept of the subject of the investment and innovation process is very comprehensive in content and to date has not been clearly defined at the legislative level, both lawyers and economists have quite actively discussed it. One of the most common approaches in economic literature is the separation of IIP subjects into three enlarged groups [7-9]:

- topics of IIP, regulating investment and innovation;
- IIP entities involved in the creation and implementation of innovations;
- IIP entities that finance innovation.

The interaction of these groups of IIP subjects is reflected in Fig. 1.

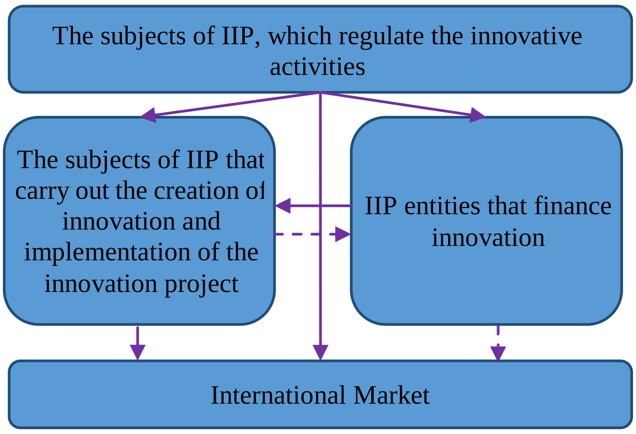


Fig. 1. Interaction of significant groups of subjects in the process of international investment and innovation activity

This approach to the identification of groups of IIP subjects is rather conditional, since, in individual projects, the entities implementing the creation of innovation and the implementation of the investment and innovation project may coincide with the group of entities financing the innovation (for example, in the case of self-financing of an innovation project). The generalized model of the investment-innovation process can be represented as the interaction of the above-defined groups of IIP subjects at different stages of the innovation process from creating innovation to bringing it to the international market, i.e. in mass production/introduction (Fig. 2).

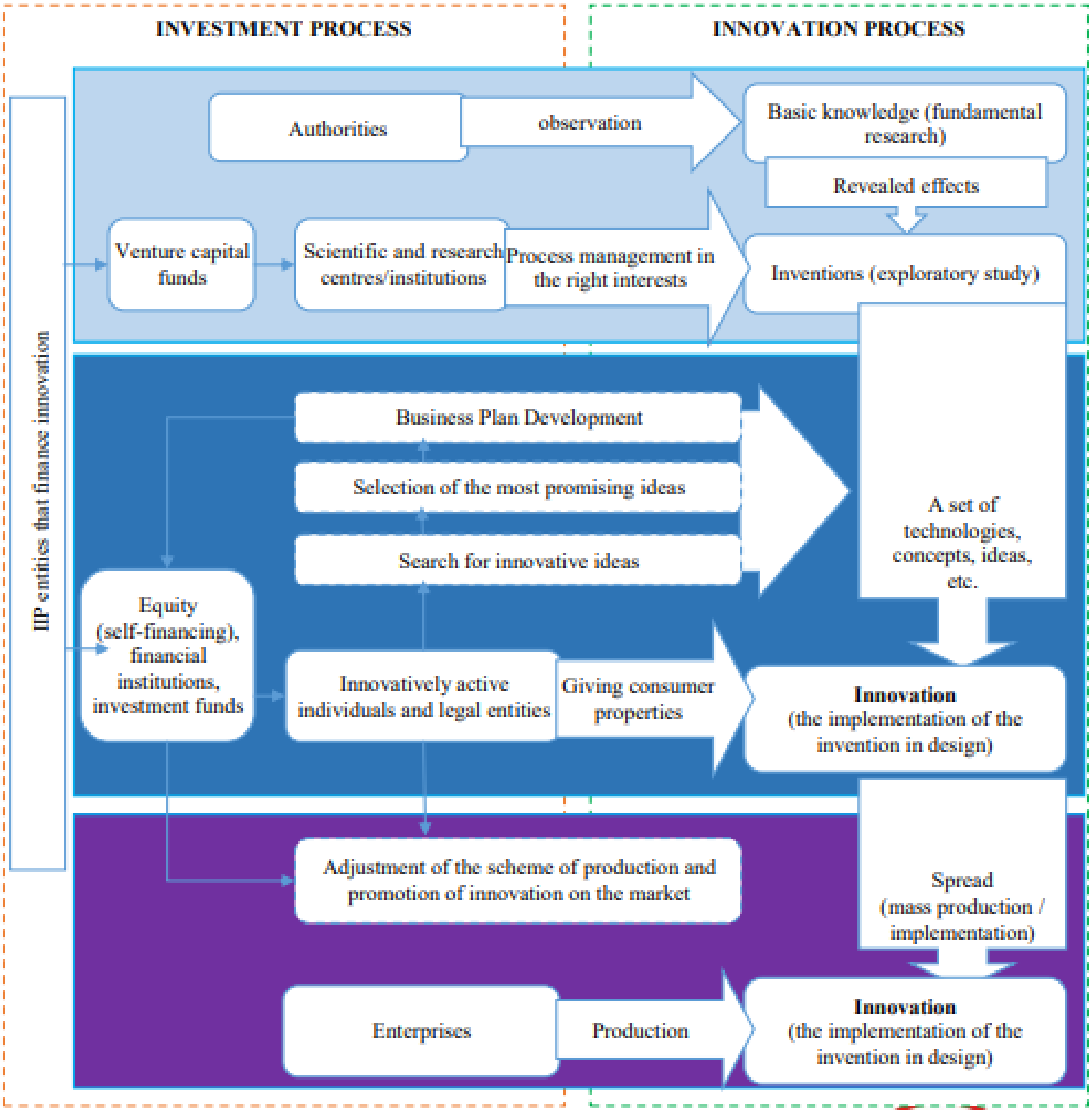


Fig. 2.Model of investment and innovation process

The dynamics of international investment and innovation processes leads to a change in the development of other areas that are associated with it directly or indirectly. Therefore, the consequence of effective management of the international investment and innovation process will affect the functioning of the related areas of activity, which ultimately helps to accelerate the development of the economic system as a whole. Thus, investment and innovation processes in modern conditions are determined by a combination of innovative and investment resources, the effective use of which contributes to both increasing national competitiveness in the global technology market and the sustainable development of the economic system.

III. METHODOLOGY OF CONSTRUCTION OF ECONOMIC AND MATHEMATICAL MODEL FOR EVALUATION OF SENSITIVITY OF INTERNATIONAL INNOVATIVE AND INVESTMENT PROJECTS

In assessing the cost-effectiveness of innovation-investment projects, it is suggested as a mandatory step to determine the sensitivity of the project, that is, the project's propensity to influence its internal parameters.

The basic approach to sensitivity diagnostics is to calculate the profitability of the project in the conditions of the most probable forecast of change of its basic parameters. The main task of diagnostics is to select the most important parameters to determine the extent of their impact on the cost of the project in case of changing the values of these parameters.

The economic and mathematical essence of sensitivity analysis is that, based on the baseline variant of the output parameter calculation, the expected average deviation of each variable (factor) is determined and the result of the output parameter calculation in the case of deviation of one of the variables from the baseline scenario.

The approach proposed in this study involves the construction of a quantitative sensitivity index $S\ (y, x_i)$.

Accordingly, some output estimation parameter (y) can be functionally expressed by internal variables (x_i):

$$y \ = \ f\ (x_1, x_2, \dots, x_{k-1}, x_k) \quad (1)$$

As an indicator of innovation-investment sensitivity of enterprise $S(y, x_i)$ to change of parameters (xi) it is proposed to calculate the ratio of relative increase of criterion to relative increase of parameter:

$$S(y, x_i) \ = \frac{\frac{y\,(x_1,x_2,\dots,x_i+\Delta x_i,\dots,x_k) - y\,(x_1,x_2,\dots,x_i,x_k)}{y\,(x_1,x_2,\dots,x_i,x_k)}}{\frac{\Delta x_i}{x_i}} \quad (2)$$

However, different (discrete) values of Them will produce different sensitivity values. In order not to do this, it is necessary to reduce them so that in the interval $(x_i - \Delta x_i;\ x_i + \Delta x_i)$, the function $y(x_i)$ for non-constant others (x) approaches the tangent at x_i. Then the sensitivity index can be determined by the formula:

$$S(y, x_i) = \frac{\frac{y\,(x_1,x_2,\dots,x_i+\Delta x_i,\dots,x_k) - y\,(x_1,x_2,\dots,x_i,x_k)}{y\,(x_1,x_2,\dots,x_i,x_k)}}{\frac{\Delta x_i}{x_i}} =$$

$$= \frac{\partial y}{\partial x_i} * \frac{x_i}{y} \quad (3)$$

The magnitude of $S(y, x_i)$ indicates how much of the original parameter (y) will change when the setting (x_i) is changed by one per cent.

Mathematical formalization in the general form of the sensitivity index corresponds to the expression:

$$S_{x_i}^{y} = \frac{x_i}{y} * \frac{\partial y}{\partial x_i} \quad (4)$$

where *y* is some initial parameter of an innovative investment project (its separately taken or integrated performance indicator);

x_i (i = 1,2, ...) - the internal parameters of the project are changing. The partial derivative $\partial y\ /\ \partial y x_1$ is a function of the sensitivity or the coefficient of influence of parameter x_i on the project performance indicator.

The ratio $x_i\ /\ y$ is entered for normalization and allows to obtain the value of $S_{x_i}^{y}$ in relative units. In Fig. 1 we present the structural and logical sequence of the stages of sensitivity assessment of innovation investment projects.

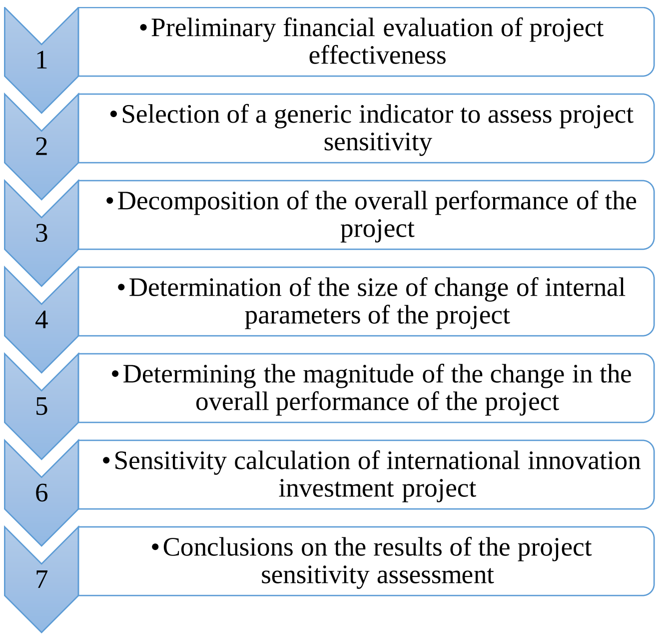


Fig. 3. Scheme of sensitivity assessment of international innovation-investment projects.

At the stage of project financial assessment, the performance indicators of innovative investment projects based on the concept of cash flow discounting (net present value, internal rate of return, discounted payback period, profitability index, etc.) are usually calculated. The choice of a generic indicator for the sensitivity assessment is made by the decision-maker.

Decomposition of a generic indicator of project effectiveness involves the selection of constituent elements (internal parameters) that have the greatest impact on the final result of its implementation. The results of such an assessment make it possible to conclude the further consideration of the project or the suitability of its inclusion in the innovative investment portfolio by the criterion of resistance to change of internal parameters. Sensitivity diagnostics is preceded by a financial evaluation of an investment project that calculates performance indicators, the most generic of which is NPV, which is calculated using the formula:

$$NPV = \sum_{t=1}^{T} \frac{F_t}{(1+r)^t} \tag{5}$$

where F_t is the net cash flow at the end of period t;

T is the project life cycle;

r is the discount rate;

$(1+r)^t$ is the current value of the monetary unit to be received at the end of period t at a discount rate r.

Net cash flow is defined as the difference between the income and expenses of the project. Net income and depreciation are taken as income, and total investment in the project are taken as an expense. Therefore, the net cash flow is calculated by the formula:

$$F_t = P_N + Am - I \tag{6}$$

where P_N is the sum of net profit calculated without taking into account depreciation and amortization;

Am - the amount of depreciation in period t;

I is the sum of investments in period t.

The amount of net profit in the general form is determined by the formula:

$$P_N = [X_n * C - (A + b * X_n) + L] * \left(1 - \frac{N_p}{100}\right) \tag{7}$$

where X_n is the volume of production of products in kind;

C - the price of production;

A - fixed costs for production;

b - variable costs per unit of output;

L - liquidation proceeds from the sale of the investment object (accounted only in the last period);

N_p - Income tax rate for operating companies.

Substituting formula (7) into formula (6) and simplifying the expression, we obtain for Np = 18% (operating income tax rate):

$$Ft = 0.82 \cdot Xn \cdot (C - b) + 0.82 \cdot (L - A) + Am - I \tag{8}$$

Most significantly affect the amount of net cash flow, and therefore the NPV, the volume of production in kind and the price of production. To simplify the calculations, we introduce the notation (B):

$$B = 0.82 \cdot (L - A) + Am - I \tag{9}$$

Then the formula for calculating net present value takes the form:

$$NPV = \sum_{t=1}^{T} \frac{0.82 \cdot Xn \cdot (C-b) + B}{(1+r)^t} \tag{10}$$

Based on expression (10), it is proposed to evaluate the sensitivity of a project NPV to changes in:

- the volume of production in kind;
- product prices;
- the value of the discount rate.

For this purpose, partial derivatives are obtained:

$$\frac{\partial NPV}{\partial x_n} = \sum_{t=1}^{T} \frac{0.82 \cdot (C-b)}{(1+r)^t} \tag{11}$$

$$\frac{\partial NPV}{\partial C} = \sum_{t=1}^{T} \frac{0.82 \cdot Xn}{(1+r)^t} \tag{12}$$

$$\frac{\partial NPV}{\partial r} = \sum_{t=1}^{T} (-t) \cdot \frac{0.82 \cdot Xn \cdot (C-b) + B}{(1+r)^{t+1}} \tag{13}$$

These parameters can be changed both individually with the same others, and at the same time. In the first case, it is sufficient to use the appropriate derivative to find the sensitivity according to (4), and in the latter case, when all three parameters change simultaneously, it is necessary to use the sensitivity of the three variables according to the gradient:

$$grad\,(NPV) = \sum_{t=1}^{T} \frac{0.82 \cdot Xn}{(1+r)^t} \tag{14}$$

Then the relative change in NPV due to small and independent absolute deviations of the parameters Xn, C, r (nXn, ΔC, Δr) can be defined in the first approximation as:

where i x NPV ∂ ∂ is a function of NPV sensitivity to parameter xi.

The value of NPV NPV NPV S пока = is an indicator of the sensitivity of an investment project based on the criterion of net present worth. It shows how the deviations of the selected parameters affect the change in NPV, which allows you to choose one or more projects from many alternatives for sustainability criteria.

The SNPV value obtained from the calculations allows us to estimate the NPV's resistance to changes in the internal parameters of the project (production volume in kind, product prices and discount rates). Obviously, the project that meets the minimum value of the SNPV module has the highest stability.

Possible changes to project parameters can be determined based on expert judgment. At the same time, the task of the experts is reduced to the following two areas: 1) to determine the most influential parameters for the project implementation; 2) determine the most likely directions for changing these parameters. In the calculations according to formula (15), for comparative results, the relative changes of parameters should be equal (for example, 1%). To improve the accuracy of the calculations, it is possible to take into account the probability when determining the direction of change of the internal parameters of the project.

IV. RESULT AND DISCUSSION

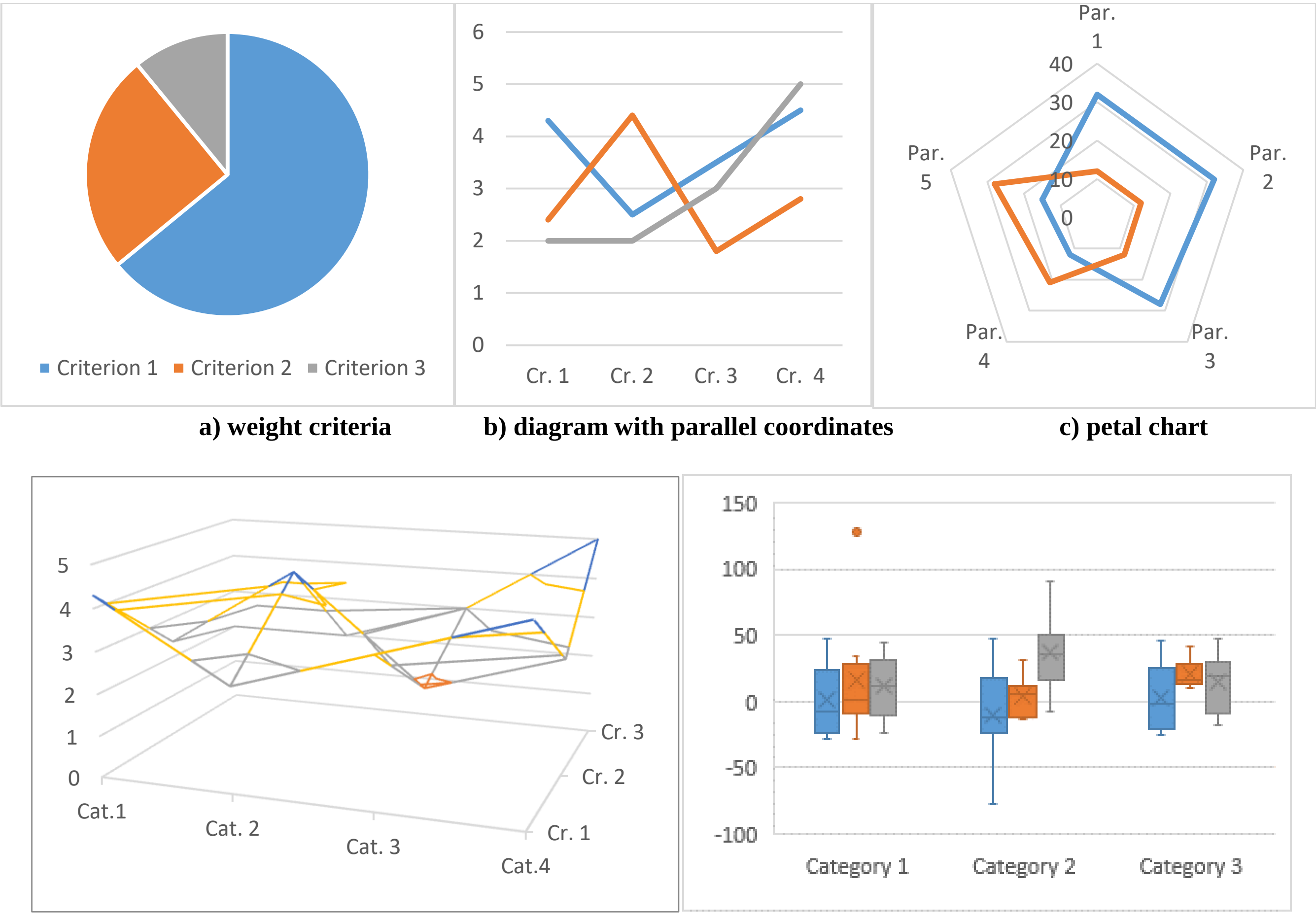
Therefore, the proposed sensitivity indicator can be used in evaluating the performance of investment projects and is recommended as additional to the performance indicators proposed in the current literature. Thus, sensitivity diagnostics makes it possible to assess the stability of an innovation investment project to changes in its internal parameters, which increases the effectiveness of managerial decision-making at the enterprise. The versatility and complexity of the proposed approach are that the developed methodological tools allow:

- use it for industrial enterprises of any form of ownership and organizational, legal form;
- take into account the factors of internal influence on the project implementation process;
- to evaluate the impact of several parameters at the same time on the overall indicator of the effectiveness of an innovation investment project;
- use the results obtained as an independent monitoring tool or as part of the project management system at the enterprise.

V. CONCLUSION

Sensitivity analysis is critical for validating and accurately determining the numerical model obtained using economic-mathematical modelling. Moreover, the expert receives a large number of tables at the output [9-10]. However, the tabular data itself does not bring much benefit to the decision-maker. To analyze data in such situations, visualization has been increasingly used recently. Visualization helps to combine the strengths of man and computer: creativity and speed.

Many software applications provide various methods for graphically analyzing sensitivity, including diagrams similar to those in Fig. 4. Using visualization methods allows you to compare objects in the face of uncertainty, check the stability of the resulting solution, provide all kinds of scenarios for the final order of alternatives, and much more.



a) weight criteria **b) diagram with parallel coordinates** **c) petal chart**

d) colourless volumetric surface diagram **e) moustache box diagram**

Fig. 4. Methods for conducting a graphical sensitivity analysis

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