Section 4. Mathematical and instrumental methods of economics

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The design of multifunctional products: the composition of operations and minimization of costs of resources  
(the case of design software)

The article is compiled based on the research findings conducted with support from the Russian Foundation for Basic Research (RFBR) — the project 15–01–06324/15 “Modeling of production and administrative processes for an express evaluation and optimization of resource intensity of goods and services: formation of universal methodical and tool providing”

Abstract: The author’s approach to the formation of the composition of operations and algorithms for optimization of resource intensity of the design of multifunctional products — software — is considered. The formed set of operations and algorithms can be used in the design of multifunctional products in various subject areas.

Keywords: design products process, functional plenitude, market segments, visual and simulation models, object design, optimization of resource intensity.

Problem definition. With the development of scientific-technological progress the goods and services delivered on the market — cars, planes, smartphones, computers, software products, even refrigerators and washing machines — become more complicated. The number of the realized functions of many market products is estimated in hundreds and thousands. For example, the number of functions of the software products (SP) for automation of the operations in the back office of investment company allocated by E. E. Pyatina exceeded 300, the number of software functions for document flow automation — 500 (Evgeny Pakhomov), the number of the software functions for automation of accounting in budgetary organizations — 900, to be exact, 985 (Svetlana Shirobokova). Also the number of modifications of products of the same intended use grows. For example, the quantity of commercial software products for automation of accounting, supervisory follow-up, registration of personnel and some other products is estimated in thousands.

It is obvious that resource intensity of design processes of such multifunctional commercial products is quite high. Besides, in the course of design of software there are difficulties related to the reasonable choice of tools of design from a set of the competing software tools used for development of software products.

One more problem is the choice of external appearance, design of the projected product. After all different people, potential buyers, often prefer different options of the interface of the program and of the appearance of products. So, judging by the Internet data, when purchasing a car, women are interested in color and form of the body, and men are interested in the technical characteristics. Besides, for different products of the same intended use the costs of service and maintenance can also differ significantly. For example, dispersion and coefficient of variation of maintenance costs for cars of one class, but different manufacturers are really high: total maintenance costs with usage of vehicle of 30 thousand km. for cars of one class differ ranging from 9.8 to 34.6 thousand rubles.

Naturally therefore at the beginning of the design process there appears a set of questions: How to choose the option of appearance of the projected products that will be optimum from the point of view of demand and sales volume? How is it possible to estimate quickly the costs of labor and financial resources for the design of complicated, full-function commercial products? What functions need to be provided in the projected software? On what market...
It is necessary to orientate the developed software? We will try to give the answers to these questions below.

1. Evaluation of functional plenitude of the software presented in the market

Preliminary remark. Though the objective of this work are complicated information and software systems, the described algorithm can be applied to evaluation of functional plenitude of other operational characteristics of any complicated systems having tens, hundreds and thousands of functions (properties, features, realized services, etc.). For example, the computer program, which is based on the offered algorithm, was successfully used not only for the primary intended purpose, but also for the formalized analysis of texts (text files).

Algorithm of evaluation. At the initial stage of design process it is necessary to study functional plenitude of the best-selling commercial software products of the same intended use. It will allow the formation of structure of functions of the projected software product reasonably. For the evaluation of functional plenitude of commercial software the usage of the described in [1; 2] approach appears to be economically feasible. Besides, considering information and software products, firstly, it is necessary to get the quantitative assessment of how (in what degree) the projected program will be able to meet the requirements of potential buyers to functional plenitude. Secondly, it is important to reveal the best systems by the criterion of functional plenitude. It is also desirable to define the list of functions realized by all SP of the leading companies in the market.

It will be recalled that in modern software products the number of the functions (functional operations), which they carry out, can reach several hundred. It is obvious that in these conditions it will hardly be possible to compare software products on functional plenitude by traditional methods (manually). Note that the offered formalized approach proved to be applied usefull and was repeatedly used in the comparative analysis of real software products (on the carried-out functions). Here we will consider one of its programatically realized modifications.

Algorithm of comparison. Let us assume that $Z = \{Z_i\}$ ($i = 1, 2, \ldots, n$) is a set of the compared software products (contender software); $R \{R_j\}$ ($j = 1, 2, \ldots, m$) is a set compiling dictionary of the $\{Z_i\}$ functions realized by the software products.

We will present the initial information as a table which elements are defined as follows:

$$X_{ij} = \begin{cases} 1, & \text{if } j\text{-function is realized by } i \text{-software product.} \\ 0, & \text{if it isn’t realized (is not carried out).} \end{cases}$$

Let us distinguish the software products $Z_i$ and $Z_k$ ($i, k = 1, 2, \ldots, n$) and introduce the following notation:

- $P_{ik}^{(0)}$ – the number of functions carried out by $Z_i$ and $Z_k$, i. e. $P_{ik}^{(0)} = |Z_i \cap Z_k|$ - the size of set intersection of $Z_i = \{X_{ij}\}$ and $Z_k = \{X_{kj}\}; \{j \in m; \ X_{ij} \cap X_{kj} = 1\};$
- $P_{ik}^{(0)}$ - the number of functions realized by the software product $Z_i$, but not realized by the software product $Z_k$, i.e. $P_{ik}^{(0)} = |Z_i \setminus Z_k| - the size of set intersection of $Z_i = \{X_{ij}\}$ and $Z_k = \{X_{kj}\};$
- $P_{ik}^{(0)}$ – the number of functions realized by the software product $Z_k$, but not realized by the software product $Z_i$, i. e. $P_{ik}^{(0)} = |Z_k \setminus Z_i| — the size of set intersection of $Z_k$ and $Z_i;$
- $P_{ik}^{(0)}$ – the number of functions realized by the software product $Z_i$ and $Z_k$, i.e. $P_{ik}^{(0)} = P_{ik}^{(1)} + P_{ik}^{(1)} + P_{ik}^{(0)}.$

For the assessment of what part (share) of the functions, which are carried out by the software product $Z_i$ is realized also by the software product $Z_k$, we can use the value:

$$H_{ik} = \frac{P_{ik}^{(1)}}{P_{ik}^{(1)} + P_{ik}^{(0)}}, \quad (0 \leq H_{ik} \leq 1).$$

The interrelation between the software products $Z_i$ and $Z_k$ is estimated on values of $P_{ik}^{(1)}$ and:

$$G_{ik} = \frac{P_{ik}^{(1)}}{P_{ik}^{(0)}}, \quad (0 \leq G_{ik} \leq 1),$$

where $G_{ik}$ is the Jaccard similarity coefficient.

Choosing various threshold values of $\varepsilon$ elements of matrixes of $P, G$ and $H$, it is possible to construct logical matrixes of absorption (inclusion) $P_0, G_0$ and $H_0$.

For example, elements of the $H_0$ matrix are obtained as follows:

$$H_{ik}^0 = \begin{cases} 1, & \text{if } H_{ik} \geq \varepsilon_h \text{ and } i \neq k; \\ 0, & \text{if } H_{ik} < \varepsilon_h \text{ or } i = k. \end{cases}$$

Graph drawn on logical matrixes $P_0, G_0$ and $H_0$ gives a pictorial view of interrelation between the compared software products (on the carried-out functions).

Let us denote the line with the list of functions that interest the user (have to be carried out by the software contender) $Z_e$.

Having added the line $X_{ej}$ ($j \in m$) into the table $\{X_{ij}\}$ ($i \in n, \ j \in m$), we will calculate matrixes $P^{(10)}$ and $P^{(11)}$. Then, having selected lines (software product $Z_j$), at which $P_{ej}^{(10)} = 0$ or:

$$H_{ej} = \frac{P_{ej}^{(11)}}{P_{ej}^{(11)} + P_{ej}^{(10)}} = 1, \quad (e \neq j, j \in n),$$

we will obtain the list of software products which meet completely the user’s requirements to functional plenitude of software (or any other complicated system).
Possible sequence of steps of realization of algorithm:

1) in the reference guide of the functions which are carried out by the compared software products those functions (functional operations) that have to be carried out by the conditional (really not existing) software are marked out, and the new line Ze is formed. With this line the initial table \( \{X_{ij}\} \), i.e. in the table \( Z_i=\{X_{ij}\} \) there is a line Ze \( (i \in (n+1), \ j \in m) \).

The matrices \( P_{ij}^{(10)}, P_{ij}^{(10)}, P_{ij}^{(10)}, H_{ij}^{(11)} \) \( (i,j \in n+1) \) are set up;

2) in the matrices \( P_{ij} \) or \( H_{ij} \) \( (i,j \in n+1) \) lines \( P_{ej} \) and \( He_{jj} \) \( (j \in n+1) \) are selected;

3) from n of the \( Z_i \) elements, each of which corresponds to one of the considered software products, only those are selected where \( P_{ej}(10)=0 \) or \( He_{j}=1 \) \( (j \in n) \), i.e. those software products that include the list of functions realized by conditional software product of Ze as a subset.

The user chooses one or several functions which interested him from the total set of functions, and these functions supplement the line Ze; then process repeats, beginning step 2;

4) on matrix \( P^{(10)} = P_{ij}^{(10)} \) consecutively for \( P_{ej}(10)=1 \), \( P_{ej}(10)=2 \) etc. the table B is set up; in this table the functions provided in Ze, but which aren't realized by a Zj package are listed; and on matrices \( P^{(11)}, H_g \) and \( G_0 \) for the chosen threshold values (\( \varepsilon \) ) it is possible to allocate and present tables of a subset of the general (or often realized) functions, as well as to estimate interrelation degree between the analyzed software product on the carried-out functions, etc.

**Example of realization of algorithm.** We will assume that table 1 contains the data on the functions (\( R_j \)) that are carried out by program systems (\( Z_i \)).

| Name of the software product | \( R_1 \) | \( R_2 \) | \( R_3 \) | \( R_4 \) | \( R_5 \) | \( R_6 \) | \( R_7 \) | \( R_8 \) | \( R_9 \) | \( R_{10} \) | \( R_{11} \) | \( R_{12} \) | \( R_{13} \) | \( R_{14} \) | \( R_{15} \) | \( \sum_{i=1}^{15} R_j \) |
|-------------------------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| \( Z_1 \)               | 1      | 1      | 0      | 1      | 1      | 1      | 0      | 0      | 0      | 1      | 0      | 0      | 1      | 1      | 1      | 8      |
| \( Z_2 \)               | 0      | 1      | 0      | 1      | 1      | 1      | 1      | 0      | 0      | 1      | 1      | 0      | 1      | 1      | 1      | 10     |
| \( Z_3 \)               | 0      | 1      | 1      | 0      | 0      | 0      | 0      | 0      | 0      | 1      | 0      | 1      | 1      | 1      | 1      | 6      |
| \( Z_4 \)               | 1      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 4      |
| \( Z_5 \)               | 1      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 0      | 2      |
| \( Z_6 \)               | 0      | 0      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 1      | 12     |
| \( \sum_{i=6}^{15} R_j \)| 2      | 4      | 2      | 3      | 5      | 5      | 2      | 2      | 2      | 2      | 3      | 2      | 2      | 3      | 3      |        |

As it is easy to verify that even in such elementary case \( (n = 6, m = 15) \) it is taking considerable time to carry out comparison of software by criterion of functional plentitude. But then the situations when \( n, m > 100 \) are quite usual. Therefore we will carry out the analysis, following the algorithm offered earlier.

At first for table 1 we will calculate matrices \( P^{(01)} \), \( G \) and \( H \), and then we will construct logical absorption matrices \( P^{(01)} \), \( G_0 \), and \( H_0 \), having chosen the following threshold values of elements:

\[
\varepsilon_p = 1 \left( P_{ik}^{(01)} \leq \varepsilon_p \right), \quad \varepsilon_s = 0.5 \left( G_{ik} \geq \varepsilon_s \right)
\]

and \( \varepsilon_{ik} = 1(i,k \in n) \).

**Example of realization of algorithm.** We will assume that table 1 contains the data on the functions (\( R_j \)) that are carried out by program systems (\( Z_i \)).

| Name of the software product | \( \sum_{i=1}^{15} R_j \) |
|-------------------------|--------|
| \( Z_1 \)               | 8      |
| \( Z_2 \)               | 10     |
| \( Z_3 \)               | 6      |
| \( Z_4 \)               | 4      |
| \( Z_5 \)               | 2      |
| \( Z_6 \)               | 12     |
| \( \sum_{i=6}^{15} R_j \)| 3      |
Now, having the constructed matrixes, it is easy to estimate quantitatively the interrelations on the realized functions between software of the leading sellers and at the same time to find new opportunities for strengthening in the future of competitive market positions of the projected products.

We will assume that designers of software were interested in what market software of the leading firms R2, R5, R6 and R10 functions are realized. Having addressed to the constructed matrixes, we will find out that the functions interesting the user are realized by three software products: Z1, Z3, Z4 — see the fourth column of the matrix P (P0) or the fourth line of the matrix H (H0) (coincides with Z4). Continuing work according to the described algorithm, it is easy to answer all main questions arising at a quantitative comparative assessment of information and software products by criterion of functional plentitude.

Conclusion

In the course of design process of multifunctional products the offered algorithm allows with the smallest expenses of resources and time to carry out:

- systematization of data on functional plentitude of software products of the leading sellers;
- formation of the full list of the functions realized by the software presented in the market;
- quantitative assessment of the degree of compliance of software products to requirements of the user to functional plentitude;
- allocation of group of the software products, having identical functional plentitude, for comparison of their prices and characteristics of consumer appeal.

2. Segmentation of the market by criterion of functional plentitude of the projected software product

On the basis of the conducted analysis of FP of commercial software products it is possible to carry out segmentation of the market taking into account the revealed preferences of potential buyers to various options of structure of functions of the projected software. Definitely, if results of the perquisition of potential buyers carried out by the technique [4; 5] (with step-by-step specification of rangings of the analyzed functions) are of the form presented in fig. 1, it is obvious that different groups of future buyers that range the functions offered to them differently, will buy more actively software with presence of these chosen by them functions i.e. taking into account their preferences. Now, having estimated the share of each of four market segments, it is possible to make adjustments to the developed project quickly and efficiently, having provided, for example, one or several modifications of the projected software product for concrete segments of the market.

Fig 1. Options of segments of the market
Conclusion: In the course of design process of multifunctional products the offered algorithm [4; 5] allows with the smallest expenses of resources and time to estimate the share of the potential buyers interested in a concrete set of functions of the projected products (in a particular option of ranging of structure of functions or groups of functions).

3. Evaluation of demand for the projected software products in different segments of the market

For the evaluation of the potential demand for the projected software products in different segments of the market it is expedient to use the procedure of step-by-step specification of values of demand with an assessment of characteristics of distribution. It is known that the efficiency of activity of subjects of market economy substantially depends on how precisely the demand for the offered products and services is predicted. At the same time at design of multifunctional products, as a rule, it isn’t possible to provide reliability of forecasts of values of demand on the basis of the retrospective analysis. Much more often the expert methods are used for this purpose. Thus in the course of evaluation it is desirable to stimulate as much as possible the active intellectual activity of participants of the expert group, to exclude influence of personal qualities of participants on results of evaluation, to generalize correctly the judgments of all members of expert group. Below the original algorithm [6] focused on step-by-step specification of values of demand with a simultaneous assessment of characteristics of distribution is considered.

Features of algorithm. Specific character of the considered algorithm consists, firstly, in use of multistep procedure, on each step of which for obtaining numerical values of demand simulation modelling is carried out, and, secondly, in integration of the method of Delfi (it is developed by O. Helmer, N. Dalkey, T. J. Gordon for forecasting of the future), with the evaluation directed on receiving the generalized opinion of the group of experts on the possible range of values of the required indicator. Such association provides a number of advantages, in particular, provides to the experts participating in examination the opportunity to consider objections and proposals of other members of expert group in the atmosphere that is free from the influence of personal qualities of participants. At the same time there is an opportunity to use the so-called “informed intuitive judgment” of the expert by creation of such conditions when the expert can actively interact with other experts in this area or in the areas concerning other aspects of the studied problem. Selecting experts for participation in examination, besides objective characteristics (position, work experience, education, etc.) it is desirable to consider their assessment of own competence (most often on a 10 point scale). Thus direct communication of experts with each other is replaced with sequence of steps, on each of which the full cycle of examination including informing the specialists on results of the previous step is carried out.

We will assume now that the described integration with the method of Delfi is realized. But the question is how to define that the collective opinion was stabilized and it is time to stop further surveys? With what probability, for example, a certain value of a required indicator won’t be exceeded? With what probability the value of an indicator will be within the preplanned confidence limits? The list of similar questions can be continued.

The only reasonable procedure for finding the answers to these questions, apparently, is the sequence of steps offered in [6].

Conclusion: In the course of design process of multifunctional products the offered algorithm allows with the smallest expenses of resources and time to carry out:

1) Simulation modelling for receiving valuations of statistical characteristics (statistical expectation, dispersion, coefficient of variation, excess, asymmetry) and distribution (in the form of tables and histograms) values of demand.

2) The automated synthesis of simulation models [7] in the course of realization of the offered algorithm for the multiple decreasing in labor costs on receiving valuations of predicted values of demand.

3) Definition of number of the step after which it is expedient to finish examination and assessment of confidence limits for a particular value of demand and probability of that its size will appear more or less certain number.

4. Comparative analysis and choice of option of appearance (design) of the interface of software products

For the economics of enterprise the problem of a comparative assessment and a choice of option of design of the object — option of the interface of the software product, option of appearance of a body of the car, etc. — is particularly actual. It is true that the right choice of the design of an object can have decisive positive impact on the main economic indicators characterizing activity of the enterprise: on the profit size, on competitive market positions, on the level of financial stability, etc. As an example confirming this thesis it is possible to provide the results of one of researches presented on the Internet in the field of automotive industry. It was found out that when choosing the car the female customers pay attention mainly to the form
and the color of the body (unlike male customers who are more interested in technical characteristics). It is easy to guess that the choice of an option of design of body of the car can mean either milliard profits, or milliard losses for the automobile company (after all the number of the women buying cars grows almost exponential). It is obvious that as it concerns the personal comparative judgement of appearance of the object and thus it is impossible to receive an assessment of options of design by results of natural, physical experiments and tool researches, it is possible to compare the options of design of the object only when using expert evaluation. Expert evaluation of characteristics of objects is a component of many procedures of preparing decisions. In [8] the correct procedures, focused on step-by-step use of Kemeni’s distance and median line and non-parametric methods of statistics when comparing options of appearance of designer object, are offered.

Conclusions: In the course of design process of multifunctional products the offered algorithm allows with the smallest expenses of resources and time:

1) To carry out the correct comparative assessment of options of design of object — options of the interface of the software product, options of appearance of a body of the car, etc.

2) To allocate the interconnected subsets of opinions of experts and to carry out the analysis of the reasons of such interrelation.

5. Choice of tools of design and testing of software

Today in the world there is a set of free and commercial tools facilitating the design and testing of software.

The question is which of the program tools it is expedient to choose in each case and what way to carry out this choice, on the one hand, to minimize costs of design process, and on the other hand, to receive a program application, optimum by criteria of consumer appeal.

After all depending on the chosen tools the input requirements (labor, financial, time resources) on realization of the design process can differ significantly: spends of time and financial resources for acquisition (purchase) and development of software will be different; these resources are used for the evaluation of functionality of the software, i.e. definition of what functions of the project-ed application can be realized by the considered design tool, with what labor costs and with what quality. The list of such questions can be continued.

In [9; 10] we offer a universal technique of the statistical analysis of the input requirements for performance of business processes in various subject domains, including the assessment of labor input to design processes of the program applications created by means of various tools.
6. Development of the user’s manual for the projected software products

At the final stage of design of software product the development of user’s manual (instruction) is carried out. In the course of formation of the manual it is necessary to define, for example, the extent to which the instruction for the user is well made? How in each particular case to estimate the amount of expenses of time for studying of the user’s manual? How to define probability of practical understanding of particular material for the set time?

To answer these questions it is expedient to be guided by work [12] in which the technique is described that allows to receive valuations of expenses of time for understanding of any training material under various conditions of formation of initial information, to estimate statistical characteristics of expenses of time (statistical expectation, dispersion, coefficient of variation, excess, asymmetry) and distribution (in the form of tables and histograms) by means of simulation modelling (when forming initial information: in the course of questioning of trainees, according to natural experiments and by results of expert surveys). On the basis of results of simulation modelling it is possible to estimate confidence limits for a particular value of expenses of time for studying of the user’s manual.

Conclusion: In the course of design process of multifunctional products the offered algorithm allows with the smallest expenses of resources and time to carry out:

1) Processing of opinions of trainees and:
   • to assess probability of understanding of the user’s manual (instruction) in particular time;
   • to compare, using the methods of nonparametric statistics, the labor costs on development of different versions of the user’s manual.

2) The experimental evaluation of characteristics of distribution of time for understanding the user’s manual (instruction) and evaluation of the share of those who has the required knowledge, abilities, skills, competences.

3) The expert evaluation of expenses of time for understanding the user’s manual (instruction), being guided by the objective, intuitively acceptable quantitative criterion — the emergence of stability in answers of experts fixed in the analysis of dynamics of coefficient of variation.

Conclusion

1. The author’s approach to the formation of the composition of operations and optimization of resource intensity of the design of multifunctional products — software — is considered.

2. It is offered to use the original algorithms allowing with the minimum expenses of resources and time in the course of design of multifunctional products to carry out:
   • comparative evaluation of functional plenitude of the products of the same intended use introduced to the market;
   • segmentation of the market taking into account structure of functions of the projected products,
   • forecasting of demand for the projected products in various segments of the market;
   • comparison of options of appearance (design) of the projected products;
   • the optimum choice of tools of design and testing of products;
   • minimization of expenses of time for understanding the user’s manual (instruction).

3. The formed set of operations and algorithms can be used in the design of multifunctional products in various subject areas.

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