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Multi-Factor Optimization and Factor Interactions during Product Innovation

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Abstract
In this paper, we develop core of an expert system for planning of innovation. The practical outcome of the paper is based on rules determination for search of perspective innovation and its distinguish from commercially unperceptive innovation. The second practical outcome of the paper is a research of interactions between factors during optimization of the product.

In general, we gain process synergy, which can be a source of competitive advantage during product innovation in the presence of organizational complexity by systematically moving through the process definition, control, and improvement elements. The improvement elements can cause interactions between these elements (or factors/process parameters). First, we have to distinguish between synergistic and antagonistic interactions. For synergistic interaction can be used graphic illustration - lines on the plot do not cross each other. In contrast, for antagonistic interaction, the lines on the plot cross each other. In this case, the change in mean response for factor at low level is noticeable high compared to high level. Searching for positive interactions leading to the creation of synergies in the performances we can do at each stage of management innovations. At first, we realize only part of the possible gain, with unrealized potential remaining. Using process control, over time, we stabilize our process and obtain additional limited gain. Using process improvement, we can realize additional gain (it looks as short vertical line during the time), with some potential gain remaining. When new, feasible options develop, we can redefined our process and continue with our control and improvement efforts. Hence, each process-related issue definition, control, improvement has a distinct role to play. Confusion between roles or the omission of any of the roles creates disharmony and frustration in the production system, which ultimately limits production system effectiveness and efficiency. Sometimes, in the presence of confusion, it is possible that effectiveness and efficiency may decrease. In this situation, we hope to learn from our negative factor interactions (or failures) and subsequently improvement trends in long term with using sophisticated methods and own intuition.

This paper objective is to create rules for planning innovation expert system. According to this rules will be possible to distinguish perspective innovation from commercially unperceptive innovation. The second paper objective is to explore interactions between factors during a product optimization. For this purpose will be used the methodology based on minimization of logic functions and design of experiments (analytical tools of DOE).

Key words:

Innovation, expert system, multi-criteria optimization, effectiveness, efficiency, synergy, process improvement, logic function, redundancy factor, design of experiments.

1 Introduction

In current business management, inovation strategy is often connected to the possibility of creating a competitive advantage, based mainly on a wide range of production benefits. One of the critical factors to initiate diversification is the increasing frequency of changes in a company's environment, and also an increase in competitive pressure expressed by shortening a product's life cycle The problem is well-known (ILBERY, 2006). As a result, the advantages resulting from both vertical and horizontal process integration are reduced. Because there are usually more innovative ideas to widen a business' activities than it would be normally possible to implement, it is essential to choose the ideas with the largest potential for commercial success. This article focuses on the design of classifiers that would enable the create the factor optimization and factor interactions investigation during a product innovation.

2 Methods

This paper objective is to create rules for planning innovation expert system. According to this rules will be possible to distinguish perspective innovation from commercially unperceptive innovation. The second paper objective is to explore interactions between factors during a product optimization. For this purpose will be used the methodology based on minimization of logic functions and design of experiments (analytical tools of DOE).

3 Results and Discussion

We have to establish four binary variables for the oral formulation of the function to differentiate the perspective vision of strategic diversification. First, we will define the system inputs to evaluate the strategic potential of innovation and its binary association:

Innovation criteria (coefficient):

K_i, where is: $i \in \{1,2,3,\}$ a $K_i \in \{0,1\}$

Criteria (coefficient) *K*1 – Residual potential of commercialized diversification (ZPKD) represents the actual potential in the product competitiveness:

$$K_1 = \prec \begin{matrix} 0 \\ 1 \end{matrix} \succ \textit{coefficient ZPKI} \prec \begin{matrix} \text{occur between } \langle 0; 0{,}5) \\ \text{occur between } \langle 0{,}5; 1\rangle \end{matrix}$$

The product (business plan) residual time created within diversification ***tR,*** that is expressed through the time rate between the time of the used change in the producer's portfolio and the assumed time of diversification lifecycle (time that the farmer has the production capacity available for production during the diversification activities). The other factor is the so-called Product Residual Unsaturation created within diversification ***nR,*** which is characterized by the relation among the number of producers that already commercialized similar products and the number of producers that (not only within their activities' diversification) use the market opportunity (or are motivated by grants) to modify their production portfolio during the lifecycle of the private farmer's diversified activities life cycle.

In case we want the ZPKD to be the quantity with growing values preferences, it is essential to subtract the residual time ***tR*** and the residual saturation ***nR*** from 1. Then we count the residual diversification time **tR** as:

$$t_R = 1 - \frac{t_i}{t_n} \qquad \textbf{(1)}$$

where:
ti = the time of the product usage that is created within the activities diversification (in years);
tn = assumed time of the realized diversification lifecycle (in years).

The residual innovation unsaturation *nR* is expressed as:

$$n_R = 1 - \frac{n_i}{n_n} \qquad \textbf{(2)}$$

where:
ni = the number of producers that already commercialized a similar product (to the product created within the diversification activities),
nn = the estimated number of producers that use a similar product to modify their product portfolio during the diversification life.

Due to the fact that both ***tR*** and ***nR*** are ratio quantifiers, it is possible to fuse them or to intersect them. If we define the domain of definition for ZPKD as: 1,0*PKD*□, it is necessary to define the residual potential of commercialized diversification by the intersection between ***tR*** and ***nR***:

$$ZPKD = \sqrt{t_R \times n_R} = \sqrt{\left(1 - \frac{t_i}{t_n}\right) \times \left(1 - \frac{n_i}{n_n}\right)}\;; \qquad \textbf{(3)}$$

ZPKD is formed by the square power because variations ***tR*** and ***nR*** are being multiplied from the maximum values. Therefore, it is essential to extract the square root of these variations to make the ZPKIrepresentative as a one-dimensional quantifier (as a geometric average). For instance, a product, made thanks to the farmer's business activities diversification, hit the market one year ago and has the supposed 5-years long lifecycle's length. A similar product has been produced by 2 out of 4 competitors.
According to (3) ZPKD is equal to:

$$ZPKD = \left(1 - \frac{1}{5}\right) \times \left(1 - \frac{2}{4}\right) = 0{,}632 \approx 63\%\ z\ \max(ZPKD)$$

If we assume a linear growth in number of producers in time, using the particular market urge (state grant policy, supply leakage in the particular market segment, etc.), the reference value of the ZPKD will occur between ⟨min *ZPKI*, max *ZPKI*⟩ and it is in value 0.5. The question is, whether the ZPKD should occur in front of the 0.5 borderline or behind. Of course there is an answer that the ZPKD should be higher than the reference value 0.5 (ideally equal to maximum that is 1). However, this single-valued definition does not respect the differentiated business strategies that use besides diversification strategies also integration strategies. Exactly those agro-businessmen that use for instance vertical integration (forward and backward) to create a competitive advantage could be advantageous to establish a product that has the ZPKD value smaller than 0.5. This contribution focuses mainly on evaluating the efficiency of strategic diversification that is applied on its production portfolio. Someone, who tries to set a competitive advantage based on business activities risks lay-out, will a priori assume that the ZPKD value should be above the 0.5 value (max = 0.5) for the positive innovation judgment.
;

Criteria (coefficient) *K2* – Financial evaluation of the necessary investment to diversification realization

There are many of various dynamic methods used for investments evaluations (concerning the development and implementation of the particular product portfolio diversification), such as the discount time of return, the internal profit ratio etc.) NPV method – Net Present Value – which enables the immediate recognition of non-profitable investment (it commonly equals to 0). If the investment is financially non-profitable, this method enables to clearly compare it with other innovation alternative which will be more profitable. Net Present Value is calculated as:

$$NPV = \sum_{i=1}^{n} \frac{CF_i}{(1+r)^{tn}} - IN \qquad (4)$$

Coefficient (criteria) *K3* – Risk of the innovation commercial success

Business risk, connected to commercial success of the offered product, is commonly defined by probability factors We estimate the empirical record that is helpful while recognizing these. We divide those into the relative percent occurrence through the histograms and the additive curve. Based on the probability division law, we try to find the probabilities of the particular values of the random quantity. Discrete quantities characterizing the risk of the new product's/service's development are usually described by this law. By a certain level of abstraction and fulfilment of the condition of the "properly short" period of marking the monitored quantity (for example product's demand), we are able to mould the discrete quantity upon the probability volume *f(x)* – as the following relation:

$$P(x_1 < X \leq x_2) = \int_{x_1}^{x_2} f(x)\, dx$$

(5)

Random quantity *X* reaches values *x* and particular probability $P(X = xi)$ for each xi reaches values *p(x).* Furthermore, this random quantity *X* reaches values *x* in the interval *(x1, x2)* with the probability that equals to *f(x)* integral after increments *dx* when the following conditions are fulfilled:

$$x_1 \leq x_2 \quad a \int_{-\inf}^{+\inf} f(x)\, dx = 1 \qquad \textbf{(6)}$$

After implementing the fuzzy set **I** for all free guiding variables, it is possible to proceed to the fuzzification itself - the method was significantly improved (KOSKO, 1997). This procedure is illustrated in the figure 2.1.

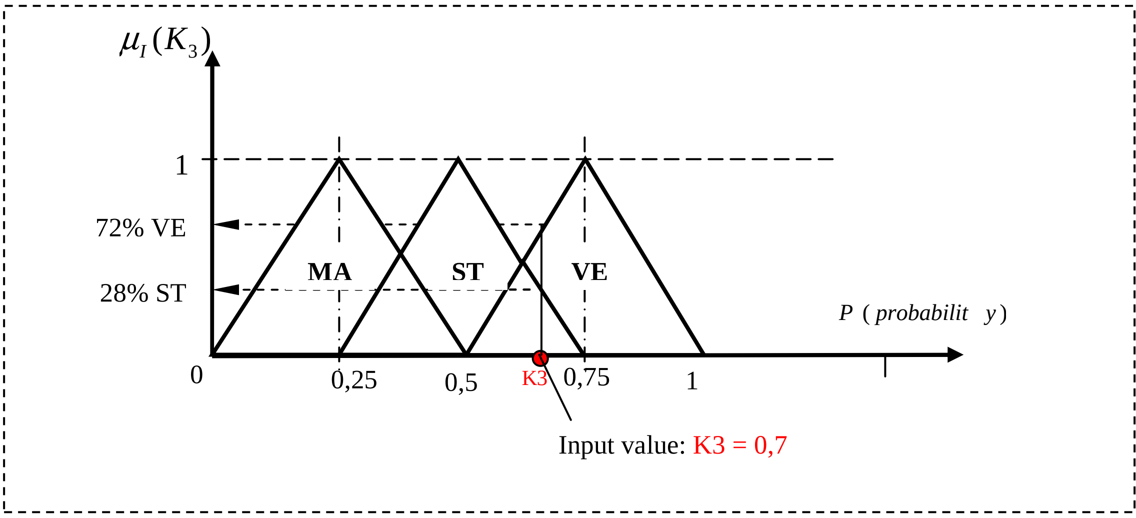

Fig. 3.1 Fuzzification of risk of the innovation commercial success

Figure 3.1 illustrates the assignment of point values of the criteria for the **risk of the innovation commercial access K₃** to the fuzzy set represented by the three subsets (MA, ST, VE). This assignment is done by the method of the so-called relevance (membership) function estimate in a parametric way. Its principle is based on the expert estimation of three points (parameters) of the input function for each subset. Parameter, which is the leftmost, is excluded from the fuzzy set (for a subset of MA it is the point [0,25 , 0]). The second point that we determine is one that certainly belongs to the fuzzy subset. For our case of a subset of MA it is **of the innovation commercial access K_3** value belonging to the top of the "triangle", therefore the point [0,25 , 0]. If this point definitely belongs to the fuzzy set, we can guarantee 100% membership rate, i. e. in the range of our scale by the value of 1. This means that for the input value, in our case 25 % of risk probability, the fuzzified value = 1 is assigned. This yields a top of the fuzzy subset of MA ([0,25, 1]). The third parameter that is specified is the point that is still included into the fuzzy subset. In our case, it is [0.5, 0]. Following that determination, we can define the fuzzy subset of MA. Its geometrical interpretation represented by the triangle MA is obtained by combining the three identified parameters, i. e. points [0, 0], [0,25 , 1] and [0 .5, 0].

In an analogous way, as shown in Figure 3.1, we would find the other two subsets ST and VE. The practical question is, in what other way than an expert way it is possible to determine the position of centroids of the fuzzy set, respectively the range of these fuzzy sets. References [x] offer the solution by means of the weight functions.
The weight values w_{MA}, w_{ST}, w_{VE} were received from the ratios of central points (centroids) for single output fuzzy sets. If the fuzzy set MA value of weight function equals one (i. e. $w_{MA} = 1$), then remaining two weight functions (w_{ST}, w_{VE}) will be calculated from the ratios of centroids of these sets to the centroids of the MA set. The

position of centroids on the horizontal coordinated axe for fuzzy set of MA is equal to 0.25 points (weight function for the fuzzy set of MA was equal to 1. At the same time, the ratio of weight function to the value of a relevant centroid should be the same (constant) for all fuzzy sets. If we express this condition in a mathematical way, we get:

$$\frac{w_{MA}}{centroid(MA)} = \frac{w_{ST}}{centroid(ST)} = \frac{w_{VE}}{centroid(VE)} = konst \;\; ;$$

From this it follows: $centroid(ST) = \frac{w_{ST}}{w_{MA}} \times centroid(MA) = ;$

$$centroid(VE) w_{VE} = \frac{w_{VE}}{w_{MA}} \times centroid(MA) = .$$

Such generally conceived weighting functions can then be transformed into interval units (variables), by means of which the relevant fuzzificated variable is characterized. More sophisticated methods can be seen in the use of methods for the design of experiments, specifically using the Full Factorial Experiment (FFE). The following procedure is indicated to determine the fuzzy set ST (middle) for Fuzzification of **Risk of the innovation commercial success**. Here we use the idea that the entire range of input values corresponding to this set should have, due to the interaction with other significant factors (**residual innovation unsaturation**, F**inancial evaluation of the necessary investment to diversification realization**) such a variability of output values (here the agregated vaulue), which would not exceed a predetermined reliability interval (here chosen at 95%). If we verified that all values within the interval of the fuzzy set have little interaction, that means that we can use all the values from the fuzzy set, and thus we can optimize the production process according to another criterion (for example the economic one, with the cost optimization of production given by the durability of the production system). If we verify that the change of fuzzy set interaction for the **Risk of the innovation commercial success** of the set ST is not important between the extreme points of this set, then we can use the whole range of values of this fuzzy set to optimize the inovation process without the system reduction of the output quality of the products.

For this inovation optimization process, we have employed a Full Factorial Experiment (FFE) (MONGOMERY, 2008) and each trial was replicated twice to observe variation in results within the experimental trials. The results of the FFE are shown in next Table 3.1.

Trial	Trial	K1	K2	K3	Response	

(standard order)	(randomized order)	Cutting speed ***v*** ***(A)***	Cutting depth $\boldsymbol{a_p}$ ***(B)***	Feed ***f*** ***(C)***	(aggregated unit)		Average (aggregated unit) K2 K3
1	***4***	***-1***	***-1***	***-1***	***1.757***	***1.745***	***-1 -1***
2	3	-1	+1	-1	1.326	1.368	***+1 +1***
3	2	-1	-1	+1	1.671	1.720	$A_{B,C(-1)}$
4	***1***	***-1***	***+1***	***+1***	***1.802***	***1.738***	1.7605
5	***8***	***+1***	***-1***	***-1***	***1.905***	***1.896***	***-1 -1***
6	7	+1	+1	-1	1.890	1.963	***+1 +1***
7	6	+1	-1	+1	1.878	1.867	$A_{B,C(+1)}$
8	***5***	***+1***	***+1***	***+1***	***1.744***	***1.709***	1.8135

Tab. 3.1 Results from a 2^3 full factorial experiment and average response values

The relative difference between average response $A_{B,C(+1)}$ and $A_{B,C(-1)}$ can be computed using the following equation:

$$RD = \frac{A_{B,C(+1)} - A_{B,C(-1)}}{\frac{A_{B,C(+1)} + A_{B,C(-1)}}{2}} = 0.29658 = 3\ \% < 5\%\ significance\ level$$

(Fuzzy set size is therefore all right)

4 Conclusion

In this paper, we develop core of an expert system for planning of innovation. The practical outcome of the paper is based on rules determination for search of perspective innovation and its distinguish from commercially unperceptive innovation. The second practical outcome of the paper is a research of interactions between factors during optimization of the product.

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