Application of the theory of decision making under risk and uncertainty at modelling of costs

Aplikace teorie rozhodování v riziku a neurčitosti při modelování nákladů

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Abstract: The costs functions are mentioned mostly in the relation to the Break-even Analysis where they are presented in the linear form. But there exist several different types and forms of cost functions. Fist of all, it is necessary to distinguish between the short-run and long-run cost function that are both very important tools of the managerial decision making even if each one is used on a different level of management. Also several methods of estimation of the cost function's parameters are elaborated in the literature. But all these methods are based on the past data taken from the financial accounting while the financial accounting is not able to separate the fixed and variable costs and it is also strongly adjusted to taxation in the many companies. As a tool of the managerial decision making support, the cost functions should provide a vision to the future where many factors of risk and uncertainty influence economic results. Consequently, these random factors should be considered in the construction of cost functions, especially in the long-run. In order to quantify the influences of these risks and uncertainties, the authors submit the application of the Bayesian Theorem.

Key words: Bayesian Theorem, cost function, fixed cost, variable cost, probability

Abstrakt: Nákladové funkce jsou zmiňovány většinou v souvislosti s analýzou bodu zvratu, kde jsou potom prezentovány jako funkce lineární. Existují však různé typy a formy těchto funkcí, přičemž je v prvé řadě nutné rozlišovat mezi krátkodobou a dlouhodobou nákladovou funkcí. Obojí jsou velmi důležitým nástrojem manažerského rozhodování, i když každá z nich je použitelná na jiné úrovni managementu. V literatuře je rovněž několik metod odhadu parametrů nákladových funkcí. Všechny tyto metody jsou však založeny na výstupech finančního účetnictví z minulosti, přičemž finanční účetnictví není schopné prezentovat náklady v rozlišení na fixní a variabilní a kromě toho je účetnictví v mnoha podnicích značně přizpůsobeno potřebám zdanění. Jako nástroj pro podporu manažerského rozhodování by pak nákladové funkce měly poskytovat jistou predikci do budoucnosti, kde však podstatnou roli hraje řada náhodných faktorů, které významně ovlivňují ekonomické výsledky. Z tohoto důvodu by pak tyto náhodné faktory měly být uvažovány také při konstrukci nákladových funkcí, zejména pak těch dlouhodobých. Autorky v práci navrhují, za účelem zakomponování faktorů rizika a neurčitosti do konstrukce nákladových funkcí, užití Bayesova teorému.

Klíčová slova: Bayesův teorém, nákladová funkce, fixní náklady, variabilní náklady, pravděpodobnost

In economics, a cost curve is a graph of the costs of production as a function of the total quantity produced. Cost functions are mentioned mainly in the context of the Break Even Point Analysis that is a methodological tool of profit management. In a free market economy, this analytical tool is used by the managements to find the optimal point of production, where the highest profit is realized. Without any knowledge of cost functions, such analysis is not applicable. Nevertheless, the real company management uses cost functions rather rarely. Profit planning in connection with a plan of production, respectively with a plan of sales is possible to rate only as some multiples of the values taken from the plan costing.

The basic problem of cost functions construction objectively does not consist in finding a functional relation between the scope of production and the

amount of costs. The main complication rests in the incapacity to divide cost into fixed cost and variable cost that is the consequence of the improper accounting systems in the companies. Not many managers in the Czech Republic really know what possibilities an properly adjusted accounting evidence might offer. Then the most of managers gain information from the final outcome of accounting, it means from the accounting statements. The established manner of the Profit and Loss Statement presentation in the classification by nature, that is still the prevailing format in the Czech Republic, seems to be irrelevant from the managerial decision making point of view.

OBJECTIVES AND METHODS

In the professional literature, many methods of cost functions construction are described. Nevertheless, all those methods are based on the past data. It means that there are no factors of risk included in making decisions for the uncertain future. The objective of the authors´ work is to originate such concept of the cost functions construction that would consist in the combination of the estimation of cost connected with the scope of production and the estimation of cost connected with the uncertain development of the internal and external environment of the company in future. This concept is supposed to be a certain form of probabilistic model of the entity's cost.

At achieving the objective of the work, the authors focused on the manners of presentation cost that would be relevant for the purpose of the management of cost and then also for the purpose of profit management. Moreover, they are interested in the application of the proper statistic methods of prediction of cost in dependence on the scope of production. The authors combine these statistic methods with the probabilistic approaches based on the combination of a priori and a posteriori probabilities, it means mainly with the Bayesian Theorem.

The main part of the work is elaborated using the method of modelling based on the logical method of deduction.

PRESENTATION OF COSTS IN THE ENVIRONMENT AND CONDITIONS OF CZECH COMPANIES

The basic requirement of every method of modelling of cost is a relevant measurement of cost in such a structure that enables the adequate classification of cost. In general, the classification of cost is based in a wide terminology the importance of which lays in defining the concepts of different economic substance of cost, different approaches to their measurement, and different consequences of their occurrence. The terminology used in connection with the presentation of cost is based on four kinds of the decision making tasks. In these tasks, the costs present the object of decision making. These are as follows:

– items of cost spent
– purpose of cost spending
– type of costing
– dependence of costs on the scope of production (Fibírová et al. 2007)

The primary source of information about costs of a company is its accounting, especially the Profit and Loss Statement as one of the financial statements that present the outcomes of accounting. Regarding the historical consequences of the Czech accounting system, in most of companies, costs are monitored and presented in the classification by nature. This classification considers the economical substance of cost in the moment of its first spending. Undoubtedly, it might be possible to assume that such a situation has its basis in the inveterate manner of the Profit & Loss Statement presentation it means from the Profit and Loss statement in classification of incomes and costs by nature. This is still the prevailing form of the statement, probably because, according to the Czech Accounting Law, which has been the only allowed form of the Profit & Loss Statement until 2003.

If the classification of costs by nature is used, it is necessary to set up also the proper analytical evidence of costs. Without such analytical accounting evidence of costs, any classification of cost by nature has zero predicting capacity. But in this case, neither the analytical evidence of costs is able to ensure the tangible evidence about the generation of profit. It causes that it is not possible to allocate costs to the particular output. This way, Fibírová and Šoljaková (2005) state that "from the view of the classification of costs by their nature, it is not possible to quantify profit immediately."

More information is held in the classification of costs by purpose. This way, costs are monitored in the connection with the process of output generation. There exist also different levels of records; three basic classification groups are distinguished there:

– Costs of production
– Costs of sales
– Costs of administration (Petřík 2005)

Nevertheless, the purpose of cost spending on is not always clear or single-valued. From the profit management needs point of view, neither the Profit & Loss Statement presented in the purpose classification

format is sufficient. In the context of profit management, it is necessary to dispose with the information about costs and the purposes of their spending but mainly about how these costs are changed in connection with the changes of scope and structure of production (Fibírová and Šoljaková 2005).

When mentioning the Profit & Loss Statement as one of the outcomes of accounting, it regards especially financial accounting. Generally, financial accounting is related to several classical problems. These consist especially in the following facts:

– Financial accounting is mostly focused on bookkeeping;
– Financial accounting provides no usable information because its system is adjusted improperly;
– Financial accounting serves more as a tool of the subsequent justification of a decision than a tool supporting the managerial decision making;
– A gravity centre of interest is costing, while a calculation of revenues is considered as unimportant (Horváth et al. 2004).

Then the irreplaceable function goes to the managerial accounting when the description "accounting focused on management" is possible to be accounted as a byword for it. Managerial accounting, respectively the cost accounting, is a basis of using cost at the managerial decision making (Čechová 2006). It would be also able to assess the results of the realized decisions then (Horváth et al. 2004), for example the decisions about the scope and structure of production.

"The target of managers is undoubtedly to manage properly"[1]; said in other words, the sense is to make the right decisions in the right time. In order to make this possible, the management of a company has to control the costs, and on the other side, the cash flows that are generated by the surrounding environment are needed to be kept. In the professional literature (e.g. Basl et al. 2003), these cash flows are defined as a difference between the sales and so-called fully variable costs.

PROBLEM OF DIFFERENTIATION BETWEEN FIXED AND VARIABLE COSTS

The traditional managerial accounting considers the total costs, it means the fixed and variable costs, and relates them to a certain scope of production while the general overhead costs and administrative costs are calculated through the use of the absorption rates (Čechová 2006). Fixed costs are economically indivisible, and in this way, it is not possible to ascribe them to the individual processes directly. It can be made only partially by the means of the mathematical-economic calculations. With regard to this indirection in costing, or because of it, the overhead costs are often automatically and artificially assigned to the total amount of output regardless of the total effectiveness of their spending (Strouhal 2006).

A different technique is the target cost accounting. Its common ground is represented by the customers´ requirements in the market and the target market price determined on the basis of real demand. From the target market price, there is then derived the profit margin, and also the target costs of production. It means that the method of forward link is used here. From the long term perspective, these costs cannot be exceeded, and the target costs become a basic controlling and planning limit of a company. The long term viewpoint would be agreed with the economic life cycle of production at the same time (Petřík 2005). In this case, classification of costs as fixed and variable is unfounded to a certain degree. It is especially because of immediate quantification of costs for every single phase of production's life cycle. What is missing here, that is a consideration about incorporating risk into these cost limits, not even from the demand point of view but from the viewpoint of price changes of inputs as well.

If all the costs of a company are only variable costs, then the operational profit would change proportionally to sales. This is practically impossible in the real economic life. It is obvious that costs of a company are composed of the variable and also fixed part. The proportion between these two parts is a factor influencing the changes of the operational profit[2] at the changing scope of output (Sedláček 2001). Separation of fixed costs from the variable is a basic prerequisite for the construction of company's cost functions. But the single approach of the financial accounting to costs measurement is not sufficient to fulfil this ground condition.

Fundamentally, the division of cost into the fixed and variable part is based on the rhythm of the consumption of costs that are the inputs of the process of output production in the given period. From this point of view, e.g. Janout (1989) uses the classification of costs as frequently spent[3] and potential[4] costs.

[1]Quotation according to Basl et al. (2003).
[2]Structure of costs influences not only the operational profit but also cash flows of a company.
[3]Variable costs
[4]Fixed costs

Frequently spent are those costs which are linked to the realization of a single product, and are fully consumed within this realization. For any other unit of production, these costs need to be spent again, frequently. Then these are the variable costs, and their total amount depends on total scope of production. On the contrary, consumption of fixed costs is connected with a certain time period during which these costs assure the level of production capacity or the general conditions for a certain scale of business activities. That is why they are called the potential costs (Janout 1989).

In agricultural companies, the problem of fixed and variable costs distinguishing has a rather similar form. Škorecová and Farkašová (2008), whose work was focused on the calculation systems in agricultural enterprise, mentioned that costing compiled in accordance with the legislation based on accounting evidence cannot provide a sufficient information background for the managerial decision making, and it might lead to improper decisions and threaten the economic performance of the existence of an enterprise.

There are very few studies, especially those based on research of the specialized agriculture bodies from the past, that mention direct and overhead costs in agricultural companies. But the main part of the studies provides the figures of costs only as the "costs per hectare" or the "personal costs per hectare" (e.g. Hanuš and Hálek 2009; Szabo and Grznár 2008). This could be a good example that many calculations also in the agricultural sector are based on the financial accounting data not relevant for the managerial decision making because the accounting system in the Czech Republic is strongly adjusted to the taxation needs in many companies.

CONSTRUCTION OF THE COST FUNCTIONS

Cost functions are an important tool of the managerial decision making in the field of production. They are very important not only in the frame of the operational production management but the cost functions play an irreplaceable role especially from the strategic point of view. Then, the particular cost function is a mathematical description of the relation between costs and the volume of production in a certain company. Thus, cost function reflects the values of the total costs for every volume of production (Echaudemaison 1995). In such a context, total costs are the function of the production volume, which is in general mathematically written as the equation

$$TC = f(Q)$$

The equation

$$TC = f(Q) = FC + v \times Q$$

represents relatively the simplest cost function in a linear form. This function is based on the precondition that costs follow the volume of production proportionally. Nevertheless, such relation of these two variables is not a rule and costs depending on the volume of production may be changing progressively or degressively. For these cases, according to the literature (e.g. Synek et al. 2006), the relations between the total costs and the volume of production are constructed as quadratic functions;

$$TC = f(Q) = FC + v \times Q + v \times Q^2$$

for the total cost changing over-proportionally in relation to the volume of production or

$$TC = f(Q) = FC + v \times Q - v \times Q^2$$

in the situation when the total costs in relation to the volume of production grow under-proportionally. The use of other types of mathematic function is not common.

The single modelling of cost functions differs depending on time perspective that the cost function should follow. In general, there are two types of cost functions, short-run cost function and long-run cost function. In the short-run cost function, there are included both variable costs and fixed costs. It is obvious and based on facts that fixed costs (FC) are always the constant element in the cost function equation. Then, what is derived from this, it is that the above mentioned forms of the cost function are relevant for short-run cost functions only. It is given by the typical characteristic of a short time period, when in short term, it is possible to change only some of the production factors, usually variable factors, while a production capacity and fixed costs connected with it are unchangeable in a short time. The construction of long-run cost functions is based on the prerequisite that every production factor can be changed in the long time period. From the long term point of view, the fixed costs do not exist. Long-run cost functions are based on the average costs and marginal costs then (Synek 2007).

Modelling of costs in short period

In the short-run cost function, there occur both variable costs and fixed costs. Fixed and variable costs are the parameters of the modelled short-run cost function. What is necessary and very important there is to point out that these parameters are only the estimations of the fixed and variable costs.

These estimations can be done by the use of various methods; maybe the simplest one is the method of two periods. But this method cannot be used in all cases, and if it is applicable, its results are rather inaccurate (Martinovičová 2006). On a quite similar principle as the method of two periods, there is based also the method of averages. Its inaccuracy is not as great as that of the previous one. Nevertheless, its results are still rather disputable. It is especially because this method works with the average volume of production and the average costs while these averages are calculated as arithmetic averages, and a typical characteristic of arithmetic average is its significant distortion by out-layers. These out-layers might be eliminated from the data set of course. But this step of elimination leads to the statistical data set reduction and then to the reduction of the predicting capacity of the statistical analysis as well.

With regard to the objectivity of the cost function modelling, it is possible to recommend the application of statistical methods, especially the application of the correlation and regression analysis. Nevertheless, neither by using these methods is the absolute accuracy of cost function objectively assured. Unlike the other methods, the application of statistics enables to asses the rate of confidence of the constructed cost function, respectively the cost function can be statistically verified.

Even if the results of this method cannot be considered as absolutely exact, contrary to the other methods, the possibility of confidence intervals construction exists there. Then these confidence intervals are possible to be considered as an expression of uncertainty, i.e. deviation from expectations. In short-run cost functions modelling, other factors of risk and uncertainty are not necessary to be covered up because their influences in short time perspective is relatively quite reduced.

Apparently, the most common used correlation metric is Pearson's correlation coefficient. It is quantified according to formula as follows:

$$r_{xy} = \frac{s_{xy}}{s_x s_y}$$

where

$$s_{xy} = \frac{\sum_{i=1}^{n} (x_i - \bar{x})(y_i - \bar{y})}{n-1}$$ is the covariance and

S_x and S_y are standard deviations of the two variables (Hendl 2004).

In the case of the cost function parameters estimation, the variables x and y represent the volume of production and the total costs, but these cannot be called independent and dependent variable because the correlation coefficient does not determine any direction of the statistical dependence. The correlation coefficient specifies only whether the dependence between the variables exists, and if their statistical dependence exists, how tight it is. A significant limitation of the correlation coefficients is that these metrics express the linear dependence only. Thus, if another type of dependency between variables exists (e.g. quadratic or exponential dependence etc.), any correlation coefficient is not able to measure such reliance, and value of the coefficient would approximate zero. What results from this, it is that a linear form cannot be used in order to model a cost function then.

Other, than linear dependence can be simply found out by the use of a dot chart, and consequently a relevant shape of the regress function is discovered this way. A form of the regress function, respectively its parameters are found using the method of least squares. On contrary to the correlation analysis, the regression analysis already determines a direction of statistical dependence. It means that independent variable and dependent variable are distinguished here. So if a cost function presents the total costs as the function of production volume, than the independent variable incoming to a regression model is the volume of production, the total costs are a dependent variable (Meloun and Militký 2004).

Carrying out the regression analysis out is a rather trivial matter, especially in the context of the short-run cost function's parameters estimation where the theory as well as practice leads to that the other functions than linear or quadratic are not used. Then it is not necessary e.g. to make a logarithmic transformation of variables.

The relevance or quality of the regression model can consequently be measured by the index of determination. To be more precise, the index of determinations quantifies what part, it means how many percent of the dependent variable's variation, is explained in the regression model, and what part rests unexplained (Meloun and Militký 2002).

The construction of short-run cost function is also simplified by an absence, or a very low rate of risk that is characteristic for a short period. To a certain extent, the operative management is considered as a decision making under certainty as well (Beranová 2007).

Modelling of cost in long period

The long-run cost functions modelling is based on the premise that fixed costs do not exist in the long time perspective. In the long time period, a cost func-

tion is composed of the partial short-run cost functions. A typical shape of the long-run cost function is the convex quadratic function when, according to the literature (e.g. Synek 2007), such a shape of the long-run cost function is considered as typical for the most of industrial or business branches. But objectively, a convexity of the long-run cost function does not need to be observed. Nevertheless, in accordance with the possibility of realization of the economies of scale, and then also the realization of the relative economies of fixed costs (see Martinovičová 2006), a typical characteristic of long-run cost function is that it is descending. This characteristic is valid only to a certain point, respectively to a certain volume of production. In this point, a local extreme that is a local minimum of the cost function takes place. The function changes its shape at this point.

As was already mentioned above, in the long term point of view, every cost is variable. Fixed costs are not supposed here, theoretically and practically they do not exist. In the long-run cost function, the target variable is defined as the average costs.

$$AC = f(Q)$$

The determination of an optimal volume of production is based just on finding the minimum of this function. From the optimal production volume planning point of view, subsequently in the viewpoint of the future production capacity, it is objectively necessary to know the concrete form and shape of this function. To calculate the average costs of a production unit from past data is a rather simple procedure. Complications appear at predicting the future development of these costs. The application of the analysis of time series directly for the average costs calculated from the past data, and their trend related to the future then cannot objectively be considered as the right approach; above, there was already mentioned the relation between the total costs and the volume of production. With regard to this, there can be considered as more proper the prediction of the total costs future development in relation to the envisaged volume of production. It means that the dependent variable should be decomposed into its two partial components incoming to it, and by the means of the analysis of time series to predict each one separately, while it is primarily a question of the total costs prediction.

Contrary to the short time perspective, in the long time perspective, it is not possible to eliminate the random influences from managerial decision making. That is why it is necessary to enter risk and uncertainty into the long-run cost function also in another way than only by the construction of confidence interval of regress function. Here the authors base their work on Bayesian Compromise that is combination of uncertain a priori approach to probability with also uncertain selective information about occurrence of possible future scenarios.

Because this is the case of assumptions of trends in the total costs to the future, there are many factors of risk having a substantial influence here; therefore, probably it would be better to speak about uncertainty. These random factors appear on the side of demand as well as on the side of supply, it means on the side of suppliers who influence costs of a company via prices of inputs (Ghatak and Seale 2001). The Bayesian compromise combining uncertain a priori attitude towards the probability with also uncertain selective information about which of the possible scenarios would happen in future, seems to be an expedient approach how to work a risk into a construction of cost functions. This approach uses a conditional probability

$$P(H_{ik}|S_i)$$

where the hypothesis H_{ik} poses a selective information about situation S_i. In relation to the determination of the stochastic model for the construction of long-run cost function, this hypothesis would represent a statement about the amount of the total costs at given volume of production in a certain possible future situation i that is the part of complete probability space of mutually exclusive (disjoint) events that may theoretically occur. In the context of the total costs and the volume of production, it can be written as

$$P(TC_{ik}|Q_i)$$

whereas this statement represents the probability of the k^{th} level of total costs at the prerequisite that volume of production equals the level i.

Based on the formula of the complete probability, the probabilities of every result of selective information are calculated as

$$P(H_k) = \sum_{i=1}^{n} P(S_i) \times P(H_{ik}|S_i) \quad \text{(Beranová 2007)}$$

or again in relation to the costs and volume of production written as

$$P(TC_k) = \sum_{i=1}^{n} P(Q_i) \times P(TC_{ik}|Q_i)$$

The result here is a priori probability of every level of the total costs occurrence when it is the complete probability at the same time. As it is obvious from the formula, two types of probability are used here.

The unconditional probability, i.e. the probability of a certain volume of production, and also the conditional probability that is interpreted above in the context of hypothesis H_{ik}, feature here. Considering that costs are a continuous random variable, it is necessary to transform this variable into the form of a discrete variable. The simplest method of such a transformation is the division of costs into intervals, i.e. interval (or scaled) variable is obtained, and every interval is replaced by one value, usually by the mean or arithmetic mean of interval. Probability assessment, the unconditional as well the conditional one, which are worked with here, are rather simply realizable by the means of a posteriori statistical approach to evaluation of probability that comes out from the data on total costs and volume of production from the past. Based on these data, the relative frequency of every level of production (here already presented as interval variable) is figured out. Then the relative frequency of every level of the total costs, as interval variable as well, is enumerated for every level of the production volume. Consequently, these relative frequencies would be considered as the objective probabilities in the stochastic model. The usage of the table arrangement seems to be a good approach as it is presented in Table 1.

Moreover, this statistic model can be continuously improved, that is by the quantification of a posteriori probability as follows.

$$P(S_i|H_{ik}) = \frac{P(S_i) \times P(H_{ik}|S_i)}{P(H_k)}$$

respectively

$$P(Q_i|TC_{ik}) = \frac{P(Q_i) \times P(TC_{ik}|Q_i)}{P(TC_k)}$$

If these probable future cost are related to various levels of production volume, then the probable average costs would be the result, i.e. the target variable in a long-run cost function. Finally, the probabilities are figured out while these probabilities are conditional again, and their values represent the probability of a certain volume of production i at the precondition that in the given period, the cost would be spent in the amount k. Then, these are the probabilities of achieving certain total costs that feature as dependent, i.e. the target variable in the long-run cost function. The plan of production then would be related to such a level of the average costs the probability of which is the highest. It is

$$AC_{opt} = \max P(Q_1|TC_{ik})$$

The level of production volume identified in this way can be considered as the optimal decision when the expected average amount of total costs is completed according to the Bayesian Criterion of decision making under risk. Basically, it goes about the weighted average of total costs that are taken into account for this level of production. Here, the weights of particular levels of costs are just the allocated a posteriori probabilities. Thus

$$E(TC) = \sum_{\substack{k=1 \\ i=1}}^{m} TC_k \times P(Q_i|TC_{ik})$$

At the highest probability, the real amount of the total costs would range about this determined theoretical value of the total costs.

As a summary, this procedure can be performed in two steps. In the fists step of the model, a priori probability of occurrence of every level of costs that is considered for each scope of production is calculated. The second step consists in a posteriori probability calculation that is the conditional probability of a certain scope of costs occurrence under the prerequisite of certain scope of production. The plan of production should be related to such average costs that have the highest a posteriori probability then.

CONCLUSION

The goal of the submitted article was to present the concepts of the cost functions modelling in connection

Table 1. General stochastic distribution for the cost function construction

$P(Q_i)$	Q	TC				Σ
		TC_1	TC_2	...	TC_m	
$P(Q_1)$	Q_1	$P(TC_1\|Q_1)$	$P(TC_2\|Q_1)$	...	$P(TC_m\|Q_1)$	1
$P(Q_2)$	Q_2	$P(TC_1\|Q_2)$	$P(TC_2\|Q_2)$	...	$P(TC_m\|Q_2)$	1
⋮	⋮	⋮	⋮	⋮	⋮	⋮
$P(Q_n)$	Q_n	$P(TC_1\|Q_n)$	$P(TC_2\|Q_n)$	...	$P(TC_m\|Q_n)$	1
1	Σ	X	X		X	X

Source: Authors

with the factors of risk and uncertainty that cannot be eliminated at the strategic managerial decision making, it means at the decision making about the production capacity and the scope of production. These decisions are based just on the cost functions.

The real rate of cost-function using in companies is rather disputable. It is especially because of certain difficulties consisting in the relatively elementary viewpoint of their construction that is distinguishing between fixed costs and variable costs. Moreover, if it regards the cost function in the long period, it would be necessary to count with the random factors as well, because they have a substantial influence on the results of decisions. In the field of the production volume and production capacity, the cost functions should be the tool of the managerial decision making support.

The article presents the authors' approach to the problem of the cost functions construction in companies. It is the result of their primary study that will be continuously verified and subsequently developed into the form of the concrete models and applications.

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