# Variational Online Budgeting Taking into Account the Priorities of Expense Items

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## Abstract

The paper describes the methodology of variational interval budgeting in a system with hierarchical structure of expense items. The priorities of expense items can be specified at any level of hierarchy. To account for the actually existing information incompleteness, the methodology provides the ability to input data and receive the results as numeric segments. The ability to clarify the budget plan in the course of its implementation is also provided. The article presents main characteristics of the working online service "Cost Planning" and example of the farm budget planning.

## Introduction

The planned revenues of states, corporations and most of individuals depend on sales volumes, market prices, exchange rates and other factors that determine the changes in economic situation. The greater anticipation of the forecast, the less reason to represent the result as a point, i.e. exact number. However, even for the state budgets expenditures are planned on the basis of point assumptions about the amount of income. The requests of expense items and the planning results also have a point representation. Therefore, the budget plans are inevitably inaccurate and need to be remade in the course of implementation. Furthermore, sometimes a set of income sources and expense items changes at different levels of hierarchical details of the planned budget. All these factors should be considered when developing the budget planning methodology (Ilyin, 2013).

The software products known to the authors provide point representation of data and results: in particular, BizBudg Online (BizBudg Online, 2016), Budget Cruncher 3.10 (Budget Cruncher, 2016), PlanGuru (PlanGuru, 2016), Questica Budget (Questica Budget, 2016), etc. One of the lists of modern products, which include means for solving problems of budgeting, can be found in (Capterra, 2016).

The authors perform the scientific research "Creating the methodology of informatization of normalized economic mechanism and software implementation of expert resource planning based on e-services" in the Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences. The first phase of software implementation includes a set of Resource Planning Online Services (www.res-plan.com). In 2015 creation of theoretical foundations of the informatization methodology was finished (Ilyin, Ilyin, 2013; Ilyin, Ilyin, 2014b) and the interval cost planning method (Ilyin, Ilyin, 2014a; Ilyin, Ilyin, 2015) was implemented in the first online service. The method takes into account the actual incompleteness of information for planning budgets.

When planning a farm budget, it is especially important to take into account the information incompleteness, because the projected values of income and expenses depend not only on the market situation, but also on environmental factors.

The presented methodology of the variational interval budgeting in a system with hierarchical

structure of expense items, where priorities may be set at any level of hierarchy, and the online service "Cost Planning", which implements this methodology, have no known analogues.

## Materials and methods

### The approach to budgeting

The problem of budget planning is considered as a specialization of the more general problem of interval planning the costs of an arbitrary resource. The problem has the informal statement, containing the mandatory and orienting rules. The mandatory rules include restrictions on the consumption of the resource to ensure the feasibility of solution, and limitations that define non-redundant satisfaction of the requests for resource. The orienting rules define the direction of the search for solution. A solution always satisfies the mandatory rules and satisfies the orienting rules in the extent defined by the interval specifics of the problem. If fulfillment of the orienting rules is possible, the solution corresponding to them is treated as more efficient than any other. A set and form of the rules can be changed by an expert during the search for acceptable plan.

*The interval cost planning method taking into account the priorities of expense items* is implemented in the working online service which drastically enhances efficiency and flexibility of budget planning.

The concept of Resource Planning Online Services, suggested by Alexander Ilyin, is similar to the "Software as a Service" concept, known as SaaS (Ardagna et al., 2014; Armbrust et al., 2010; Benlian et al., 2009; Chunlin, LaYuan, 2015; Jamsa, 2013; Jede, Teuteberg, 2016; Katzmarzik, 2011; Kavakli et al., 2015; Petcu et al., 2013; Rogers, Cliff, 2012; Sandholm, Lee, 2014; Trumba Corporation, 2007; Wang et al., 2010; Wei, Blake, 2010). The first difference is that res-plan.com does not store data of the users' tasks on server (this is stipulated by the reasons of security and privacy), and the second one is that res-plan.com users work in special client applications (because stability and performance of web applications depend on the browsers where they work).

In a client application of the "Cost Planning" service user specifies minimum amount of the resource as the sum of opening balance and expected income in the worst case scenario. The maximum amount of the resource should be specified as the sum of opening balance and expected income in the optimal scenario.

User also specifies a table of expense items, and for each row the lowest and the highest expected costs (or exact value) can be entered - the requests of the expense items. A separate table of details can be created for any expense item: for example, the expense item "Communications" can be detailed by the items "Internet", "Mobile phones", "Landline phone", etc. Amount of the resource allocated to the expense item will be distributed between expense items that form its details. The number of detail levels is not limited. The priorities (the weighting coefficients) can be specified for any table. Some requests can be marked as obligatory (e.g. wages or rents can rarely be reduced). Different applied precision (minimal significant value) can be set for data and results for any table.

Then, when user commands 'Allocate' from client application, it connects to the service via Internet and sends it a query for resource planning. The service (program which works on reliable server in 24/7 mode) receives the query, performs computations and immediately sends the results back to the client application. The results are the values 'Allocate min.' and 'Allocate max.' for each expense item - the plan for the worst and the best scenarios. Sum of 'Allocate min.' values complies the specified minimum amount of the resource, and sum of 'Allocate max.' values complies the specified maximum. The principle of computation is described below in the chapter "The principle of interval cost planning, taking into account the priorities of expense items". The application also displays values 'Allocate avg.' (so user can see an approximate resource allocation).

Afterwards, in the course of the plan implementation, when a part of the resource is received or spent, or more precise information on expected income or costs is obtained, user inputs the corresponding data in client application, executes the command 'Allocate' again, and gets the refined results. If the exact resource amount is specified (i.e. minimum = maximum), then the received values 'Allocate max.' can be treated as exact decision of the cost planning task.

### The advantages of the variational online budgeting

If user specifies the bounds for resource and requests cautiously and follows the plan prepared with the Service, then the probability of going beyond the budget is drastically reduced.

For each expense item user beforehand sees the bounds for possible costs, and narrows them

in the course of the plan implementation.

If upper bound is less than minimum request for some item, then user can timely attract investments, or exclude the item, or correct other costs.

If the planning results are too "tight", user can temporarily exclude any expense item from consideration: it can be done by setting a "tick" in the corresponding cell of the table.

User can simulate any real cost: set minimum request equal to maximum, mark it as obligatory, execute the command 'Allocate', and see the changes of bounds for the rest of expense items. User can manually adjust the planning results. A client application will indicate if the entered data is inconsistent.

### The principle of interval cost planning, taking into account the priorities of expense items

The resource amount and the requests of expense items are specified as numeric segments.

The values of the planned costs are computed as numeric segments also. First, the resource allocation problem is solved for the top-level expense items. Then, if any expense item has the detailing items, part of the resource allocated to the item is considered as the resource amount to be allocated between the detailing items, and the separate resource allocation problem is solved, etc. For example, part of money allocated to the item "Communications" can be allocated between the items "Electricity", "Internet", "Mobile phones", "Landline phone"; after that, part of money allocated to the item "Mobile phones" can be allocated between the items representing the concrete mobile users. Number of the detailing levels is not limited.

The priorities of expense items can be specified and used in solving each particular resource allocation problem in the hierarchy. The problem has the following informal statement.

For a numeric segment $[a, A]$ ($a \geq 0, A > 0$), which expresses the expected resource amount, segments $[b_i, B_i]$ ($b_i \geq 0, B_i > 0, i = 1...n$), which specify the requests of expense items, and weighting coefficients (priorities) of the expense items $p_i > 0$ ($i = 1...n$), it is required to find a cost plan $[x_i, X_i]$: $\{0 \leq x_i \leq b_i, X_i \leq B_i, i = 1...n\}$. Depending on presence of the resource shortage for sum of the left bounds and sum of the right bounds of the requests, one of the following situations takes place:

1) $\{b_1 + ... + b_n > a, B_1 + ... + B_n > a\}$.

   In this case the problem for the left bounds is to be solved, and then - the problem for the right bounds (see below).

2) $\{b_1 + ... + b_n \leq a, B_1 + ... + B_n > a\}$.

   In this case the left bounds are set equal to the minimum requests ($x_i = b_i$), and the problem for the right bounds is to be solved.

3) $\{b_1 + ... + b_n > a, B_1 + ... + B_n \leq a\}$.

   In this case the problem for the left bounds is to be solved, and the right bounds are set equal to the maximum requests ($X_i = B_i$).

4) $\{b_1 + ... + b_n \leq a, B_1 + ... + B_n \leq a\}$.

   In this case there is no problem: the left bounds are set equal to the minimum requests ($x_i = b_i$), and the right bounds are set equal to the maximum requests ($X_i = B_i$).

The mandatory rule for solving the problem for the left bounds:

$x_1 + ... + x_n = a$.

The orienting rules for solving the problem for the left bounds are the proportions

$x_i : x_j = p_i b_i : (p_j b_j)$ for each $1 \leq i \leq n, 1 \leq j \leq n$, where $b_j > 0$ (for $b_j = 0$ obviously $x_j = 0$).

The mandatory rule for solving the problem for the right bounds:

$X_1 + ... + X_n = A$.

The orienting rules for solving the problem for the right bounds are the proportions

$(X_i - x_i) : (X_j - x_j) = p_i(B_i - b_i) : (p_j(B_j - b_j))$ for each $1 \leq i \leq n, 1 \leq j \leq n$, where $\{B_i > b_i, B_j > b_j\}$, and $X_i : x_j = p_i B_i : (p_j B_j)$ for each $1 \leq i \leq n, 1 \leq j \leq n$, where $\{B_i = b_i, B_j = b_j\}$.

The iterative algorithms for solving the problems for the left and right bounds are described in (Ilyin, Ilyin, 2015).

## Results and discussion

The methodology of variational interval budgeting and the online service in which it is implemented, received a positive assessment in the course of discussions in the Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences, in the Moscow Technological University (MIREA), in the ResearchGate

professional network. The Support page of the res-plan.com also allows to write questions, suggestions and comments on the service.

There are no restrictions on scale of the budgeting tasks. The samples for enterprise and family budgets are delivered within client application package (it can be downloaded and used for free during 21 days). The following simple example for a farm budget demonstrates the efficiency of the service (the example purposely contains few expense items to be clear and observable).

### The budgeting example

Suppose a farmer plans a budget for the coming month, wanting to hire new worker and buy some new agricultural equipment. He has 11 000 EUR as opening balance and expects to earn 14 000 EUR during the month (total 25 000). The minimal price of equipment is 9 000, the price of the perfect one is 12 000. The minimal cost of a new worker is 1 300, the cost of the optimal one is 1 500.

### Without the service

Using a standard approach with point assumptions for income and expenses (AACE International, 2012; Barrett, 2007), a farmer gets a plan like in Table 1.

Following this plan, a farmer buys the equipment for 10 000 EUR, hires a new worker with the minimum salary, and expects the small closing balance. Then, the market situation worsens, and the real income received for the month becomes 11 000 EUR instead of the expected 14 000.

As a result, at the end of the month even for zero closing balance the farmer can be faced with the need to borrow 2 000 EUR to pay wages.

| Expense item | Allocate money (EUR) |
|---|---|
| Wages and taxes on it | 11 100 |
| Communications | 200 |
| Fodder | 1 000 |
| Fertilizers | 400 |
| New worker | 1 300 |
| New equipment | 10 000 |
| Accumulation of capital (closing balance) | 1 000 |
| TOTAL | 25 000 |

Source: own processing

Table 1: Rigid cost plan – threat to go beyond the budget.

### With the service

Using the flexible interval approach of the online service "Cost Planning", a farmer could estimate the expected resource amount (sum of the opening balance and future income) as a segment, e.g. [22 000, 26 000], specify the requests of expense items (the lowest and the highest expected costs) and their priorities (the weighting coefficients); press the 'Allocate' button and receive the following results (the applied precision is set to 10 EUR) (Figure 1).

The results ('Allocate min.', 'Allocate max.') show that new equipment should be bought for 9 780 only in the case of the maximum income. The average value 'Allocate' for the item 'New worker' is
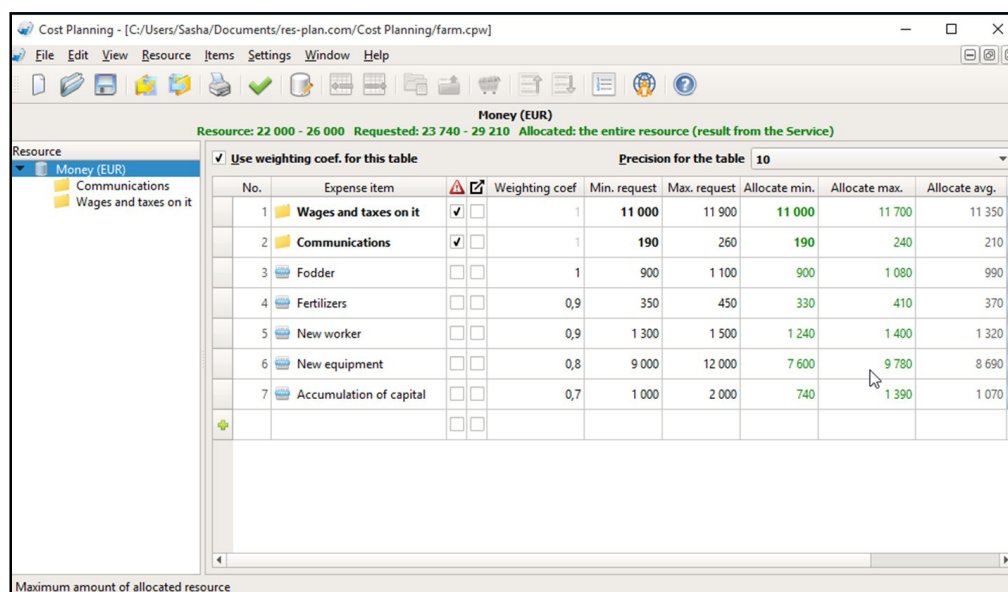


Source: own processing

Figure 1: Flexible cost plan – to be clarified step-by-step, not going beyond the budget.

1 320, so the logical decision can be to hire a worker, but wait with the purchase of equipment.

In the course of the plan implementation, when a farmer makes the real costs, he periodically uses the 'Subtract actual cost…' command from the 'Items' menu, presses 'Allocate' again and gets the refined results. When a part of revenues is received, he can modify the resource specification and re-allocate money again to get more precise plan. If things go well, the equipment can be purchased closer to the end of the month.

So the service user step-by-step narrows the bounds in the data and in the results, staying within the budget.

## Conclusion

With innovative interval algorithms implemented in the online service "Cost Planning", it is possible to solve the budgeting problems much more efficiently than using other software.

The implemented methodology drastically reduces a probability to go beyond a budget. User specifies the expected minimum and maximum amounts of money, minimum and maximum requests for expense items and their priorities. The service computes minimum and maximum values 'Allocate' for each expense item, which comply the specified data. When user beforehand sees the bounds for possible costs and narrows them in the course of the plan implementation, it is really possible to avoid critical costs, temporarily exclude some expense item from consideration; to correct the planned costs, to attract investments timely.

Usage of the service is significantly cheaper than usage of other budgeting software products (Capterra, 2016). User pays only for that periods, when he/she actually uses a Service. It is advisable to use the service for any entrepreneurs. For farms, it is especially important to compute implementable budgets in condition of information incompleteness.

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