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COST ALOCATION FOR MULTY-PURPOSE WATER RESOURCES SYSTEM - A CASE EXAMPLE

Stevcho Mitovski[1], Ljupcho Petkovski[2], Frosina Panovska[3]

Summary

Main goals of development programs are economic and social progress, thus providing prosperity and wellbeing of the population. The engineering economy is applied for alternatives structuring in case of a water resources system in order to be compared among them and decision to be made for the most favorable alternative. Upon the adoption of optimal alternative for a water resources system it is required cost allocation to be carried out between the particular parties - participants within the multipurpose system. However, there is no specified norm or code for choice of allocation method. The main criteria is to meet the specified objectives. In the paper is given brief overview of cost allocation method and application of the method "separable cost - separable benefits" in case of water resources system Plavaja, Radovis, N. Macedonia.

Key words: economic of water resources systems, cost allocation, net benefit.

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1. INTRODUCTION

Main goals of development program or strategy are economic and social progress. Namely, all contents included in development program and specific purposes of the water-economy structures (providing of water for water supply and irrigation, power production, flood protection etc) throughout raise of the national revenues lead to ultimate goal of the development programs - prosperity and wellbeing of the society. The development programs and projects are usually defined by multidisciplinary team of engineers and economists, whereas the engineers are responsible for the designing and construction of the civil engineering structures, and the economists for feasibility and sustainability of the water resources system. However, it is important to highlight the despite the active role and participation within the process, they do not have the privilege to decide whether some project or development program will be implemented or not apropos the decision is made by the society or more precisely the political representatives of the government itself.

2. SHORT OVERVIEW OF THE PRINCIPLES OF THE ENGINEERING ECONOMY

The engineering economy is science on application of economic criteria in order to select the most favorable design from group of alternative engineering designs. In case of project implementation it will produce time model with impacts that must be predicted, evaluated and compared. The principles of engineering economy lead the process of alternative structuring in order to be compared among them and decision to be made for the most favorable alternative. The evaluation process requires to predict the impacts that will occur as result of selection of the specific alternative, assessment of the magnitude for each impact and conversion into commensurable units. Pioneer work of the modern engineering economics is regarded Arthur M. Wellington [1], by his study for analysis of alternative railway locations, carried out in 1877. The acknowledgment of the full spectra of potential alternatives is of paramount importance that would prevent in the initial stage the most efficient solution to be left out. The most rational treatment of the process of alternative structuring is according to Grant [2], by specifying of five principal stands:

(1) All alternatives that are physically capable for achieving of the design goals should be clearly defined. One alternative is not to take any actions if none of the alternatives is economically cost-effective. The limitation of aspect of finance and time in most cases prevents full analysis of all alternatives. Before analysis detailing the cost from the additional information must be compared with the potential saving in case of selection of the more favorable alternative.

(2) The physical consequences of all alternatives should be identified and evaluate in monetary units. The costs and benefits that is not possible to be evaluated in monetary units should be identified explicitly.

(3) The base ground for comparison should be the difference among the alternatives. The sunk costs are irrelevant at choice of the alternatives, except in case when the have impact on future events. Each separable investment increment must regain at least equal share of revenue in order to be feasible.

(4) At alternative comparison the focus should not be placed on the differences of the non-commensurable values and consequences of the market. The arbitrary monetary values should not be categorized in the same group with the non-commensurable values due to the possibility of twisting of the economic analysis.

(5) The alternatives should be compared on uniform base.

The economic analysis is carried out in series of appropriate successive stages. Each alternative must be explicitly defined and the resulting physical consequences must be foreseen as accurately as possible. For each of the physical consequences should be determined monetary value and select discount rate, that will be applied for conversion of the time flow of the monetary values in equivalent singular value and finally to compare the alternative. The process of economic analysis includes the following steps:

(1) Specification of the alternatives. The engineering alternative is set of actions technically capable to fulfill the design goals. The engineer-planer must specify properly defined alternative with sufficient precision in order economic (monetary) and non-commensurable consequences to be evaluated so the decision makers to fully understand the essence of the alternative. Properly created set of engineering alternatives includes all possibilities for taking actions that have realistic chance of proving as optimal.

(2) Physical consequences. The implementation of each engineering alternative will produce series of physical consequences that will occur in various time domains in the future. For example, construction of intake system for water supply will produce increased production of agricultural products. The built system must be maintained, and all cost-associated items need to be planned by its nature and timeline.

(3) Cash flow diagram. All physical consequences are not relevant for the analysis so it is required to select only the relevant one. The alternatives must produce identical physical consequences, that should be eliminated because in the analysis are compared only the differences between the particular alternatives. The relevant consequences can be divided in two groups: consequences that can regarded in monetary value and consequences with monetary value for which is necessary additional determination of the non-commensurable factors. The graphic presentation of each value plotted by time is called cash flow diagram. On the standard display of cash flow diagram the cost are represented by arrows pointing downward, while the benefits are represented by arrows pointing upward. The length of each arrow is proportional to the each cost or benefit. The horizontal axis denotes the time. In case of analysis of long term projects, due to more convenient analysis and little loss in the accuracy, all cash flow within the year are by convention combined into lump sums occurring at the end of the year. On Fig. 1 is displayed cash flow diagram for hypothetical irrigation project.

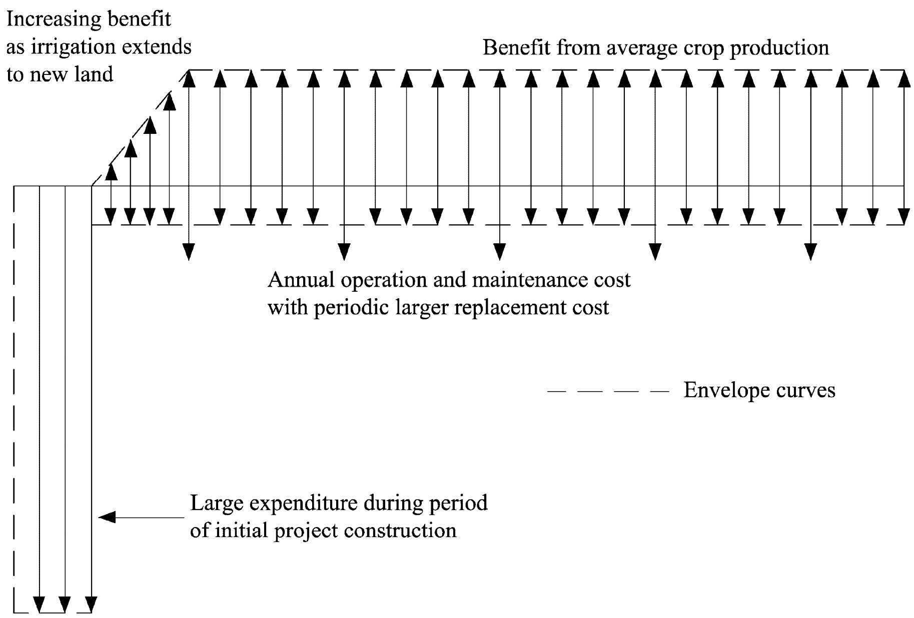

Figure 1. Cash flow diagram for hypothetical irrigation project [3].

(4) Single payment factors. At application of discount techniques for conversion of the money flow in one indicator, suitable for comparing of the alternatives, the basic objective is to convert the value from one period in equivalent value in another period.
(5) Uniform-annual series factors. Such factors marks the equivalence between values from an earlier period and the equal amounts at end of each N-year or between the N equal values of the equal amounts and an accumulated amount F.
(6) Uniform-gradient series factors. Such factors can be applied in case of equal cash flow in each year. At great number of cases the cash flow will not be equal but it fill track some patterns of the flow. The simplest pattern is by uniform increase of the gradient series, in which the cash flow is increased by constant amount between each pair of years.
(7) Non-uniform gradient series factors. The project planning often requires determination of the present worth of some monotonic but non-uniform time flow of the benefits. Such typical situations include cases when benefits are increasing by uniform annual percentage, benefits that are increasing rapidly in the early years of the life span of the project but significantly slower in the later stages, benefits that are increasing most rapidly in the middle of the project life span and benefits that are increasing most rapidly in the final period of the project life span.

3. METHOD FOR COST ALLOCATION FOR JOINT STRUCTURES

Upon the completed process of analysis of the alternatives and adoption of optimal alternative for a water resources system it is required the total cost to be allocated between the particular groups. In case of multipurpose system for water resources it is necessary to divide the cost between the concerned purposes of the system. In some cases (even in case of single purpose system) the cost must be separated between the financial responsible groups. For dividing of the total cost among the responsible parties is applied the cost allocation. The cost allocation is part of the economic analysis that determines how much each party from the project should invest. Within the cost allocation there are fixed cost that cannot be directly allocated to any purpose of the project, but taking in consideration that they must be paid, then they must be allocated in appropriate pattern in dependence of the project and the participants.
The direct cost are cost of the project elements that belong only to one cost center. If an element serves to several cost centers the difference in its cost with and without serving a center is separable cost for such element in regard of the cost center and it is determined from the project alternatives in case when it serves and does not serve to cost center. The difference between the total cost of the project and sum of separable costs is non-separable cost. Non-separable costs include joint and common costs. The joint cost occur when the project elements contribute in production of more than one output. Common cost are indirect or other fixed cost that must be paid but cannot be associated with any production operation. The cost of some project elements can be separable in regard of the group of cost centers but not in regard of any individual cost center. Non-separable cost that cannot be separated to any cost center nor group of cost centers must be allocated between all centers and cost that are separable in regard of group of cost centers, but not in respect of singular cost center, must be allocated among the cost centers that create such group. At cost allocation each party tends to gain the smallest share of the total cost and therefore the essence of the allocation is successful resolution between the conflict interests among the involved parties. Although there is no correct method for allocation, eight guiding rules are generally available [3, 4]:

(1) The allocation to any cost center should never be less than the additional cost for inclusion of that center in the project nor more than the total benefit provided by that center;
(2) The allocation sum of all cost centers should be equal to total cost of the project;

(3) The allocation method should avoid costly and complex calculations, that does not have other application
(4) The allocation process should be sufficiently "linear" and simple so it can be understood appropriately and correctly;
(5) The share (amount)allocated to each cost center determines the charge for that center for the services that he provides;
(6) The charges resulting from the allocation should be properly constant with time in order to provide market stability for the project services;
(7) The allocation helps at determination of the charge for the users on one hand, but on other hand it affects the income distribution (once cost center can have higher income that other but equality at income distribution is important component at allocation evaluation);
(8) The common structures should be managed in accordance with cost allocation.

The allocation has two major functions. First regards the revenue function apropos based on the investment the money must be raised. The balance calculations, mainly developed in the private sector, are initial point in the cost allocation model development for public works. The second function is to improve the economic productivity in case of public works.
The process of classification of the project total cost to particular cost centers takes place in two stages: (1) allocation of the total cost to project objectives and (2) the cost allocation for each purpose among the location centers. In some specific cases there is and third stage, that comprises of cost allocation from location centers among the various types of users.
First step in cost allocation is identification and classification of the separable costs on the appropriate cost center. The determination of the separable costs is in two steps. First, determination of separable costs to individual cost centers and second, determination of the separable costs to combinations, but not to the individual cost centers.
The cost allocation method identifies by the definition of cost used, amount of cost directly assigned to the respective cost center and allocation vehicles. The alternative costs that should be allocated in the matrix are the total financial cost, total financial cost without direct costs distributed to cost centers or total financial costs without separable cost distributed to cost centers. The allocation process is carried out according to matrix of cost allocation (Tab. 1). So, in dependence of the amount that should be allocated among the various parties (participants in the project), there is general division of the total cost, excluded direct cost and excluded separable cost.

Table 1. Cost allocation matrix [3].

		Amount to b e allocated		
		(a)	(b)	(c)
Vehicle		Total cost	Direct cost excluded	Separable cost excluded
A	Equal	Aa	Ab	Ac
B	Unit of use	Ba	Bb	Bc
C	Priority of use	Ca	Cb	Cc
D	Net benefit	Da	Db	Dc
E	Alternative cost	Ea	Eb	Ec
F	Smmaler of benefit or alternative cost	Fa	Fb	Fc

The methods in column (a) use the vehicle of cost allocation for distribution of the total project cost. Such methods are simplest, but they do not provide information whether the assigned cost exceed the separable costs. Methods in column (b) subtract the direct costs from the total costs

before using the vehicle to complete the allocation. Their principal advantage in respective to the methods in column (c) is that they do not require complex computer calculations, required for separable cost estimation. Methods of column (b) are favorable for cost centers with large separable costs and small direct costs. The assigned costs may not exceed the separable cost. Methods of column (c) subtract the full separable costs from the total cost. It is ideal case for such value, because from theoretic point of view, for allocation of separable costs the vehicle is not required. The proper economic analysis require separable costs to be calculated in order to equate incremental costs with the incremental benefit, the separable cost must be available the beginning of the analysis.
The methods in row A divide the residual cost equally among the cost centers. The division in equal shares is simple, but it shifts large share of the financial burden on the minor cost centers. Such method is to be applied when all cost centers provide equal or approximately equal services. The methods in row B use vehicle by measuring of the item of use of facilities and require finding acceptable unit of use. The item of facilities use is often used due to its preference for determination of fair payment, proportionally on the use and due to the resulting ease at obtaining public approval. Methods in row C allocates all non-separable costs to cost center with highest priority. Difficulty arises the problem that there is no specified modus for priorities establishment and it is not righteous to order one cost center to pay all costs. Methods in row D allocates the residual costs proportionally to net-benefits resulting from the respective cost centers. The allocation according benefits is widely applied due to the essential righteousness by which each cost center pays proportionally to its benefits. Problem occurs whether should be used all benefits or only direct benefits. On other hand, if secondary or indirect or indirect cost provide the margin of project feasibility, the allocation proportional to direct cost may exceed the direct cost. The methods in row E allocates costs proportionally to excessive costs from the alternative with lowest cost that can provide the same service. The primary value of the method is that avoids benefit calculations that cannot be adequately defined or by nature are with non-commensurable values. In case when some alternative regards as tool that will provide the design outputs, alternative costs are upper limit of the amount that cost center will pay to participate in the project. However, difficulties at defining of proper alternatives makes such method subjected to misleading. Methods in row E carry out allocation according to the lower value form excess benefits or excess cost of the alternative. Such method combines the best features and eliminates the worst features of methods in row E and D.

4. COST ALLOCATION BY APPLYING METHOD „SEPARABLE COST - SEPARABLE BENEFIT“ – CASE EXAMPLE FOR WATER RESOURCES SYSTEM PLAVAJA

4.1 INPUT DATA

The input data for the economic analysis, by financial means actualized in present worth, are the total cost for joint structures for multipurpose water resources system Plavaja (including dam and appurtenant structures), estimated at 40×10^6 € [5]. The specified cost estimation should be updated by future preparation of technical documentation (Preliminary and Basic Designs) for the adopted altermative solution.

The water resources system is planned as multipurpose project, aimed for following purposes and appropriate water users: (1) hydro power production (HP), (2) irrigation (I), (3) flood protection (FP), (4) water supply (WS) and (5) provision of environmental flow (EF).

In Tab. 2 are specified appropriately gross benefits, single-purpose and joint costs without the i-user.

Table 2. Specification of costs and benefits.

no.	Input data values	mark	unit	HP	I	FP	WS	EF
1.	Gross benefits	D_{br}	×10⁶ €	3.0	55.0	2.0	20.0	1.0
2.	Single-purpose costs	T_{ed}	×10⁶ €	1.0	25.0	0.0	5.0	0.0
3.	Joint costs without i-user	T_{zi}	×10⁶ €	40.0	30.0	40.0	35.0	40.0

4.2 Cost allocation for multipurpose water resources system

The joint cost for the dam and the appurtenant structures for WRS Plavaja are estimated at 40×10^6 €, for reservoir at normal water level at 460.0 masl. Such cost should be allocated to different parties (users) as participants in the water resources system. The allocation process will be carried out according to the concept "separable cost- separable benefit" (method Fc from the matrix). The separable cost are difference between the total cost of the multipurpose system and system cost by neglecting of the particular objective. By applying the concept for cost allocation there are two principal rules: (1) for each purpose should be allocated share of the total cost, that should not be less than from the separable cost for such purpose and (2) for each purpose should not be allocated share, greater than the benefits of such purpose or greater from the cost of some equivalent alternative. The amount of the separable cost is estimated at 15×10^6 €, so the remaining allocation amount is $40\text{-}15=25\times10^6$ €. The cost allocation will be carried out in accordance with the savings for each purpose. In order to determine the savings for each purpose it is required from benefits to subtract the separable cost, thus obtaining residual benefits. The calculation for the cost allocation is systemized in Tab. 3. In row (1) are specified gross benefits for each purpose, according to the input data. In row (2) are specified single-purpose costs for each purpose, separated from the joint cost. The benefits in row (3) are calculated as difference of row (1) and row (2). In row (4) are specified separable cost, from the available input data. The residual benefits in row (5) are calculated as difference of row (3) and row (4). The ratio in row 6 is calculated as quotient of values in row (5) and total amount of the residual benefits (end line of row (5)). Share of the joint cost, specified in row (7), is obtained as multiplication of values in row (6) and joint costs, obtained as difference of the total joint cost and total separable cost (end line of row (4)). In row (8) is specified total allocation, obtained as sum of row (4) and row (7). The sum of the total allocation of row (8) is 40×10^6 €, as the amount of the joint cost that should be allocated. The total cost for each purpose, specified in row (9), are obtained as sum of row (2) and row (8). The net-benefits for each purpose, specified in row (10), are obtained as difference of the values in row (1) and row (9).

Table 3. Cost allocation for water resources system Plavaja.

no.	amount [×10⁶ €]	HP	I	FP	WS	EF	Σ
1.	Gross benefits	3,00	55,00	2,00	20,00	1,00	
2.	Single-purpose cost	1,00	25,00	0,00	5,00	0,00	
3.	Benefits	2,00	30,00	2,00	15,00	1,00	50,00
4.	Separable cost	0,00	10,00	0,00	5,00	0,00	15,00
5.	Residual benefits	2,00	20,00	2,00	10,00	1,00	35,00
6.	Ratio	0,06	0,57	0,06	0,29	0,03	1,00
7.	Share of joint cost	1,43	14,29	1,43	7,14	0,71	25,00
8.	Total allocation	1,43	24,29	1,43	12,14	0,71	40,00
9.	Total cost	2,43	49,29	1,43	17,14	0,71	71,00
10.	Net benefits	0,57	5,71	0,57	2,86	0,29	10,00

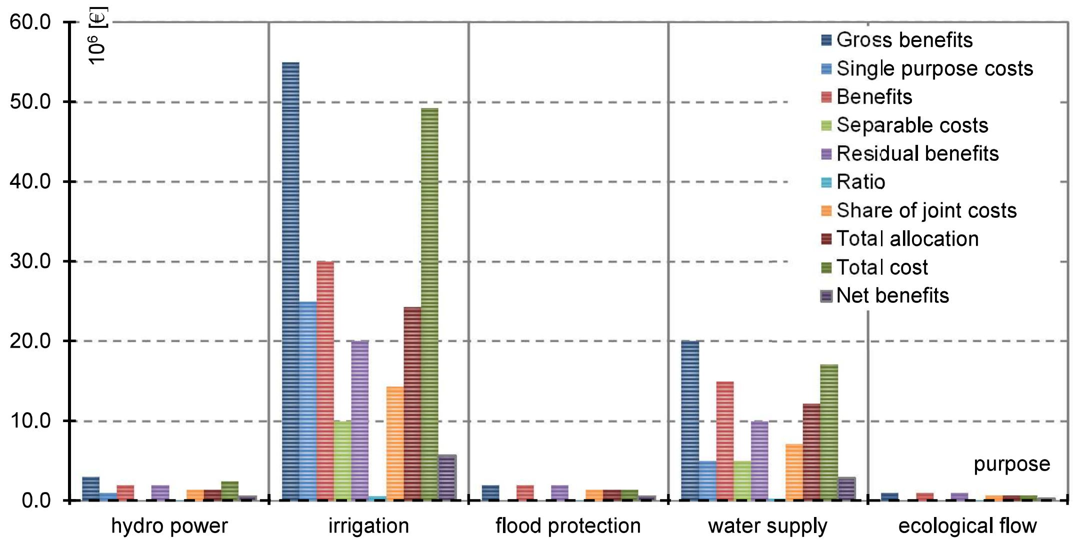

Figure 2. Display of cost allocation for water resources system Plavaja.

5. CONCLUSIONS

From the carried out analysis following conclusions can be drawn out:

(1) The engineering economy is created by merging of economy and engineering, by which of group of alternatives for a water resources system is chosen the most favorable alternative, by a multidisciplinary approach (interaction of economists and engineers of various branches).

(2) The process of economy analysis is carried out in successive stages.

(3) Most complex is the stage of explicit specification of each alternative, prediction of the alternative impact in case of variations of the factors and future events and choice of the optimal solution.

(4) The total cost of the chosen alternative must be allocated among the responsible parties within the project.

(5) From the carried out economic analysis it can be concluded that the total allocation for each purpose is higher than the separable cost and lower than the benefits, whereas the savings of the multipurpose water resources system are allocated equally.

(6) The cost allocation process directly impacts on the economic efficiency and one of the main criteria at choice of allocation method is to meet the specified social objectives apropos for each various task is applied appropriate allocation method.

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