ALLOCATION OF OVERHEAD COSTS OF LOGISTICS AND OTHER SUPPORTING ACTIVITIES TO PRIMARY ACTIVITIES OF MANUFACTURING ENTERPRISES

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Abstract

This article deals with possibilities in selecting the most accurate allocation of overhead costs of logistic and other supporting activities to primary (production) activities in cases where outputs of cooperating support activities in manufacturing enterprises are reciprocally consumed. A reciprocal consumption of outputs of supply, transport and maintenance activities, where the outputs of supply and transport activities are consumed by maintenance activities and the outputs of maintenance activities are consumed by supply and transport activities can serve as an example.

Keywords: Allocation, activity, overhead costs, supporting and primary activities, primary and secondary costs

1. INTRODUCTION

There are changes in the cost structure of production companies, share of direct cost is decreasing compare to share of overhead cost. This is mainly because of increasing investments to automation of production. Primarily it is overhead logistics cost and cost of other supporting activities that are increasing. Therefore, it is necessary to focus not only on effectiveness of overhead cost but also on allocation of these cost to primary activities of production companies and then allocation of these primary activities to final products, which are final cost object of overhead cost. This issue is mainly dealt with by the Activity based costing method [1,2,3].

Interdepartmental, reciprocally cooperating support activities have only primary overheads at the very beginning of the cost allocation process. The reciprocal consumption of outputs of support activities then causes the need to allocate not only primary, but also the subsequently incurred secondary overhead costs. The aim of this article is to offer mathematical and practical possibilities for solving this issue [4].

Supporting logistics activities in manufacturing plants include, in particular, ordering and purchasing material and energy inputs, activities related to material storage and its removal, work in progress, semi-finished and finished products, in-process handling, in-house and off-site transport (excluding material purchase). Other support activities include mainly segments of maintenance and energy supply activities.

The ultimate objective of this allocation is to transfer the total (primary and secondary) overhead costs of the support activities to primary activities. Such increased overhead costs of primary activities are further allocated to cost objects in the form of individual products or their groups (this is no longer the subject of this article).

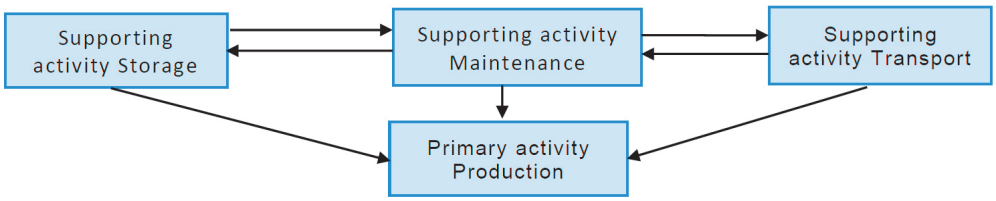

Figure 1 Example of reciprocal links between support centres [Own processing]

The problem of the allocation of overhead costs of support activities is the reciprocal cyclical consumption of outputs of their activities, as shown in a simple example of reciprocal links in the following **Figure1**.

The algorithm for allocating overheads of support activities to other support or primary activities is based on the ratio of consumption of relational quantities in absolute terms. The relational quantities should as far as possible express the causal link between the activities consumed and the cost created by such consumption.

The relational quantities are the units of measurement of individual logistic or other support activities, e.g. number of orders, number of acceptances, number of items of material or products stored and removed, number of "pallet-months" (a relational quantity expressing an occupied storage area in a warehouse and the time a pallet is stored there), activity hours, transport distance in km, energy in GJ or MWh, etc.

In literature are described three cost allocation methods of overheads cost in case of mutual consumption of supporting activities [1,5]:

- The direct method,
- The step method,
- The reciprocal method.

But these methods are not described in detail and definition of calculation algorithms is missing. Mathematic expression of these calculation algorithms is main goal of this article.

2. DIRECT METHOD OF ALLOCATION OF OVERHEAD COSTS

Under the direct method, the reciprocal consumption of outputs within the support activities is ignored. In this case, only primary overheads of support activities are allocated directly to primary activities. This method is simple to calculate because it does not take into account (ignores) the existing reciprocal consumption of outputs in support activities, as shown in the **Figure 2**.

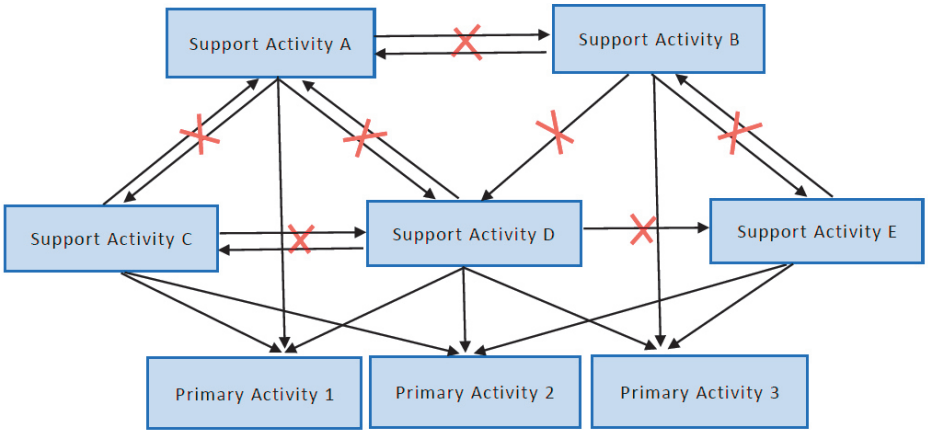

Figure 2 Example of the elimination of all interrelationships between support activities in the direct method of calculating the overhead cost allocation for multiple primary activities [Own processing]

In the direct method, only the primary overheads of support activities are allocated directly to primary activities where they are of a nature of a secondary cost. To calculate the overhead cost allocation by the direct method, it is necessary to know the amount of overhead costs allocated for individual support activities and the amount of relational quantities expressing the consumption of the outputs of these activities by other support and primary activities.

First, the overhead rates per unit of output of consumed outputs of support activities are calculated [Own processing]**:**

$$Rate\ RN_i = \frac{Z_i}{X_i} \quad \text{for i,j = 1,2,...n} \tag{1}$$

where:

Rate RN$_i$ - Overhead (primary) cost of the i-th support activity in CZK/unit of the relational quantity

Z_i - Value of the total primary overhead costs of the i-th support activity

X_i - The total amount of i-th support activity relationship quantities consumed by all other support and primary activities

Then the calculation of the value of overhead costs allocated to primary activities follows [Own processing]:

$$ARN_j = Rate\ RN_i \cdot y_i \quad \text{for i,j = 1,2,...n} \tag{2}$$

where:

ARN$_j$ - Allocated overhead costs for the j-th support activity in CZK

Rate RN$_i$ - The overhead costs rate of the i-th support activity in CZK/unit of the relational quantity

y_i - The amount of relational quantities of the i-th support activity consumed by the primary aktivity

3. STEP METHOD OF ALLOCATION OF OVERHEAD COSTS

The step method respects the reciprocal transfer of performance between the support activities, but does not take into account (ignores) any reciprocal cycles of these consumptions.

Within the scope of the step method, it is necessary to determine the successive steps (stages) of the allocation of overhead costs between support activities, with the last support activity in this procedure allocating its overhead costs to primary activities, as shown in the **Figure 3**.

This method is more accurate than the direct method if there is an existence of reciprocal cycles of handovers, but it is more laborious than the direct method.

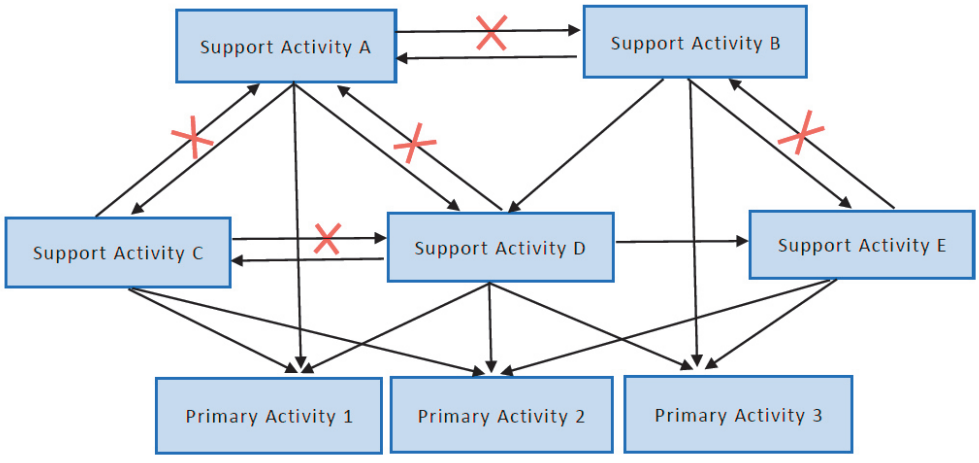

Figure 3 Example of elimination of cyclical interrelationships between support activities in the step method of overhead cost calculation [Own processing]

The aim of the step method of overhead cost allocation is to transfer the total (primary and secondary) overhead costs of support activities to primary activities, while doing so gradually within the individual steps (stages) of this allocation. For example, in the activities shown in **Figure 3**, the first step will consist of the allocation of overhead costs from support activity B to A, D and E, the second step the allocation from A to C

and B, the third step the allocation from D to C and E, and the 4th step the allocation from support activities C, D and E to primary activities 1, 2 and 3.

The calculation of the overhead cost allocation by the step method also requires the knowledge of the amount of the allocated overhead costs for individual support activities and the amount of relational quantities expressing the consumption of outputs of these activities by other support and primary activities.

Within the step method of overhead cost allocation, it is necessary to gradually allocate overhead costs within the individual steps (stages), from support activities creating outputs to support activities and subsequently also to primary activities that consume these outputs. Firstly, it is necessary to calculate the overhead cost rates of support activities generating outputs and then to calculate the value of overhead costs allocated to support and primary activities that consumed these outputs.

Calculation of the primary overhead rate of support activities within the 1st step of the step allocation method [Own processing]**:**

$$Rate\ RN_i = \frac{Z_i}{X_i} \quad \text{for i,j = 1,2,…n} \tag{3}$$

where:

Rate RN$_i$ - The rate of overhead (primary) costs of the i-th support activity in CZK/unit relational quantities

Z$_i$ - Value of total primary overhead costs of the i-th support activity

X$_i$ - The total amount of relational quantities of the i-th support activity consumed by all other support and primary activities

Calculation of the rate of the total overhead costs of support activities within the second and subsequent steps of the step allocation method [Own processing]**:**

$$Rate\ RN_i = \frac{+Z_i+S_i}{X_i} \quad \text{for i,j = 1,2,…n} \tag{4}$$

where:

Rate RN$_i$ - The overhead cost rate of the i-th support activity in CZK/unit of the relational quantity

Z$_i$ - The value of total primary overhead costs of the i-th support activity

S$_i$ - The value of the total secondary overhead costs of the i-th support activity allocated to it in the previous step of the step allocation method

X$_i$ - The total amount of the i-th support activity relationship quantities consumed by all other support and primary activities

Calculation of the value of overhead costs allocated to support or primary activity within each allocation step [Own processing]**:**

$$ARN_j = Rate\ RN_i \cdot y_i \quad \text{for i,j = 1,2,…n} \tag{5}$$

where:

ARN$_j$ - Allocated overhead costs for the j-th support or primary activity in CZK

Rate RN$_i$ - The overhead rate of the i-th support activity in CZK/unit of the relational quantity

y$_i$ -The amount of relational quantities of the i-th support activity consumed by the primary activity

4. RECIPROCAL METHOD OF ALLOCATION OF OVERHEAD COSTS

The reciprocal method fully solves all reciprocal and cyclical consumption of outputs of support activities, as shown in the **Figure 4**. The condition of the reciprocal method is that there is no self-consumption, which means that support activities do not consume their outputs themselves. Any occurrence of such self-consumption must be ignored.

The correct result of the reciprocal overhead costs allocation method is that the sum of the secondary costs of all primary activities must be equal to the sum of the primary overhead costs of all support activities.

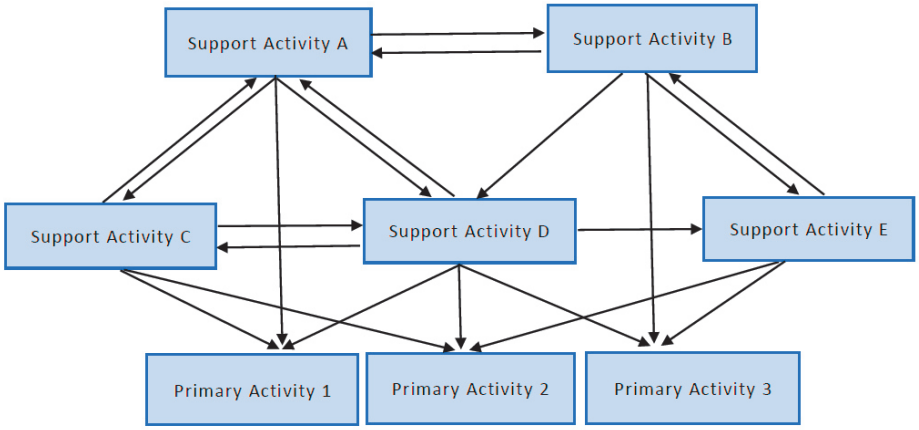

Figure 4 Example of cyclical relationships between support activities in reciprocal overhead costs allocation method [Own processing]

To calculate the overhead costs allocation by the reciprocal method, it is necessary to know the amount of the allocated primary overhead costs for the individual support activities and the values of absolute relational quantities expressing the volumes of activities consumed by individual support and primary activities.

Within application of exact decision methods for effective calculation of prices of intercompany activities we used modification of structure analysis method which is describe in following part of this article [5].

4.1. Table of outputs and inputs of reciprocally consumed activities

The calculation of the overhead allocation of support activities to primary activities under the reciprocal method is initially based on the **Table 1** below, which shows the consumption of outputs of the i-th support activities by the j-th support and primary activities. These consumptions are expressed by the amount of the relational quantities consumed.

Table 1 Consumption of outputs of support activities (in the amount of relational quantities consumed) [6]

Supporting activities generating outputs (A_i)	Activities consuming outputs of support activities (A_j)						Total relational quantities consumed (X_i)
	Supporting activity A_1	Supporting activity A_2	Supporting activity A_3	…	Supporting activity A_j	Primary activity A	
Supporting activity A_1	x_{11}	x_{12}	x_{13}	…	x_{1j}	y_1	X_1
Supporting activity A_2	x_{21}	x_{22}	x_{23}	…	x_{2j}	y_2	X_2
Supporting activity A_3	x_{31}	x_{32}	x_{33}	…	x_{3j}	y_3	X_3
:	:	:	:	:	:	:	:
Supporting activity A_i	x_{i1}	x_{i2}	x_{i3}	…	x_{ij}	y_i	X_i
Primary costs (Z_j)	Z_1	Z_2	Z_3	…	Z_j		
	Quadrant I		Quadrant II		Quadrant III		

Calculation of the total quantity of relational quantities [7,8]**:**

$$X_i = \sum_{j=1}^{n} x_{ij} + y_i \qquad \text{for i,j = 1,2,…n} \tag{6}$$

where:

X_i - The total amount of the i-th support activity relationship quantities consumed by all other support and primary activities

x_{ij} - The amount of relational quantities of the i-th support activity consumed by the j-th support activity

y_i - The amount of relational quantities of the i-th support activity consumed by the primary activity

4.2. Matrix of allocated consumption of primary overhead costs of support activities

In the previous table of inputs and outputs, the reciprocally transmitted activities can take the form of different types of relational quantities. Since the values of xij do not have to be expressed within the same unit of quantity, it is only necessary to convert the amount of the consumed relational quantities (see Quadrant I in **Table 1**) to a matrix of allocated primary cost consumption already expressed in the same unit (CZK).

The values of the allocated primary overhead costs shown in the Table 2 are calculated according to the formula [Own processing]**:**

$$z_{ij} = \frac{Z_i}{X_i} \times x_{ij} \qquad \text{for i,j = 1,2,…n} \tag{7}$$

where:

z_{ij} - The value of the primary costs of the i-th support activity allocated to the i-th support activity.

Z_i - The value of the total primary overhead costs of the i-th support activity

X_i - The total amount of the i-th support activity relationship quantities consumed by all other support and primary activities

Z_i / X_i =The rate of primary overhead costs of the i-th support activity in CZK/unit of the relational quantity

x_{ij} - The amount of the relational quantities of the i-th support activity consumed by the j-th support aktivity

Table 2 Matrix of allocated consumption of primary overhead costs of support activities (in CZK) [Own processing]

Supporting activities generating outputs (A_i)	Activities consuming outputs of support activities (A_j)				
	Supporting activity A_1	Supporting activity A_2	Supporting activity A_3	…	Supporting activity A_j
Supporting activity A_1	z_{11}	z_{12}	z_{13}	…	z_{1j}
Supporting activity A_2	z_{21}	z_{22}	z_{23}	…	z_{2j}
Supporting activity A_3	z_{31}	z_{32}	z_{33}	…	z_{3j}
:	:	:	:	:	:
Supporting activity A_i	z_{i1}	z_{i2}	z_{i3}	…	z_{ij}

4.3. Creating matrix A - coefficients of consumption of primary overhead costs of the support activities

It is necessary to create a matrix of coefficients of the allocated consumption of primary overhead costs of the i-th support activities on the total primary costs of j-th support activity from the previous matrix of the allocated consumption of primary overhead costs of support activities.

The values of the coefficients allocated to the primary overhead costs of the support centres shown in the Table 3 is be calculated according to the formula [Own processing]**:**

$$a_{ij} = \frac{z_{ij}}{Z_i} \qquad \text{(i,j = 1,2, …n)} \tag{8}$$

where:

a_{ij} - Coefficient (share) of allocated primary overhead costs of i-th support activity in total primary costs of j-th support activity

z_{ij} - The value of the primary costs of the i-th support activity allocated to the j-th support activity.

Z_i - The value of total primary overhead costs of the i-th support aktivity

Table 3 Matrix A - consumption coefficients of primary overhead costs of support activities [Own processing]

Supporting activities generating outputs (A_i)	Activities consuming outputs of support activities (A_j)				
	Supporting activity A_1	Supporting activity A_2	Supporting activity A_3	…	Supporting activity A_j
Supporting activity A_1	a_{11}	a_{12}	a_{13}	…	a_{1j}
Supporting activity A_2	a_{21}	a_{22}	a_{23}	…	a_{2j}
Supporting activity A_3	a_{31}	a_{32}	a_{33}	…	a_{3j}
:	:	:	:	:	:
Supporting activity A_i	a_{i1}	a_{i2}	a_{i3}	…	a_{ij}

4.4. Calculation of inverse matrix B - matrix of complex consumption coefficients

The inverse matrix $[E\text{-}A]^{-1}$, designated as matrix B, is calculated from the matrix [E-A], which is the difference between the single matrix and matrix A defined in the previous point.

The inverse matrix B is a matrix of complex consumption coefficients (bij), which express the increase of primary costs of j-th support activities by allocated overhead costs from i-th support activities whose outputs they consumed.

At present, the easiest way to calculate the inverse matrix is to use the MC Excel spreadsheet, using the INVERSION function to specify the area in which the matrix elements [E-A] are listed (preferably in another sheet).

To allocate overhead costs within the reciprocal method based on the already calculated inverse matrix, it is necessary to first calculate the rate of the total overhead costs per unit of the relational quantity. This rate will include both the initial primary costs of the j-th support activities and the secondary overhead costs allocated from the i-th support activities whose outputs they consumed.

Calculation of the total overhead costs rate under the reciprocal method [Own processing]**:**

$$Rate\ RN_i = b_{ij} \cdot \frac{Z_i}{X_i} \qquad \text{for i,j = 1,2,…n} \tag{9}$$

where:

Rate RN_i - The overhead costs of the i-th support activity in CZK/unit of the relational quantity

b_{ij} - Coefficient of increase in consumption of primary overhead costs of the j-th support activity by the allocated overhead costs of i-th support activities whose outputs it consumed.

Z_i - The value of the total primary overhead costs of the i-th support activity

X_i - The total amount of the i-th support activity relationship quantities consumed by all other support and primary activities

Z_i/X_i = The rate of the original primary overhead cost of the i-th support activity in CZK/unit of the relational quantity

The values of the allocated total overhead costs for a primary activity (activities) are calculated on the basis of the calculated rates of the total overhead costs of the individual support activities and the amount of their outputs in the form of relational quantities consumed by the primary activities.

Calculation of the value of total overhead costs allocated to primary activities [Own processing]**:**

$$ARN_j = Rate\ RN_i \cdot y_i \qquad \text{for i,j = 1,2,…n} \tag{10}$$

where:

ARN_j - Allocated overhead costs for the j-th primary activity in CZK

Rate RN_i - The overhead rate of the i-th support activity in CZK/unit of the relational quantity

y_i - The amount of the relational quantities of the i-th support activity consumed by the primary activity

5. DISCUSSION

The maximally accurate allocation of overhead costs of support activities is not as important for the management of support activity responsibility as it is for computing price bargaining calculations. It is here where it is necessary to know the most accurate value of the costs used to produce the final products; that is not only the direct and overhead production costs, but also the costs of the support activities whose outputs these primary (production) activities consume.

From the perspective of calculations for price negotiations it is also very important that all the above calculations of the allocation of overhead costs of the support activities are performed separately for the variable and fixed part of these overhead costs. In this context, variability refers to the relationship of the allocated overhead costs to production volume within the primary activities to which these overhead costs are allocated.

6. CONCLUSION

The most accurate calculation of the allocation of the overhead costs of reciprocally cooperating support activities is provided by the reciprocal method. In the case of a large number of support activities, this method is the most accurate, but it is also very demanding for ensuring the planning and monitoring of both the primary costs and the amount of consumed outputs (relational quantities) of support activities. The less accurate method is the step method and the least accurate but the simplest method is the direct method of allocating the overhead costs of the support activities.

It applies that the more support activities there are, the more accurate the calculation of these allocations should be. This is mainly done by the ABC Method (Activity Based Costing Method), which is intended for the most accurate calculation of the allocation of overhead costs caused by the consumption of specific support

and primary activities. For these reasons, the reciprocal method should be applied in the allocation of overheads for process-complex production.

In this article presented steps of overheads cost allocation within reciprocal method are using coefficients of complex consumption from structural model, which are created by inversion of matrix with direct consumption coefficients. These coefficients are already including all relations between elements of matrix and therefore it allows to calculate in one step cost of mutually cooperated supporting activities to primary activities.

The step method is then suitable for the allocation of overhead costs for process-simple production, e.g. in metallurgical primary production, i.e. for coking plants, blast furnaces, steel mills, continuous casting plants, continuous rolling mills and the like.

The direct method is unsuitable for the allocation of overhead costs in cases where there is a cyclical reciprocal consumption of outputs of support activities.

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