

Accuracy and Sophistication in Activity Based Costing System

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In today's world managers using computerized cost accounting systems can meet their needs to basic, consistent and reliable cost information. Since cost allocation is at the heart of most cost accounting systems, it is an inescapable problem in nearly every organization. In all cost allocation problems it is essential for managers to consider the behavioral implications of cost driver selection. Most of the cost allocation studies, have attempted to accomplish cost allocation methods within a one-by-one relationship between cost pools and cost drivers. In this research we present a new cost allocation method that attributes costs considering a multilateral relation between cost drivers and cost pools. We have used a mathematical presentation to solve the plurality observed in relationships between cost drivers and cost pools. At the end For the purpose of illustrating the concepts and technique a simple case study is presented to portray the probable differences between proposed methods.

Keywords: Activity Based Costing (ABC) system, Reciprocal Allocation Method (RA), Least Squares (LS) method.

1. Introduction

The goal of any costing system is to provide relevant and timely information for management. This information supports better management of corporate resources in producing the products or provision of services, and increasing competitiveness in terms of costs, quality, and profitability. There are three elementary types of costing system, differing in their means of allocating overhead costs to products: 1) traditional absorption costing system 2) variable costing system and 3) activity-based costing system. Traditional costing system, represented by the absorption costing system, were used for the purposes of overhead cost allocation in the last century. The absorption system usually places overhead department costs in the general or administration overhead, these having been allocated to a product using direct labour or a basis for direct cost allocation. Indeed, using such a foundation for allotting fixed overheads results in unsuitable arbitrary allocation (Drury 2001). Variable costing method that allots variable and fixed costs separately, where fixed costs are not assigned to cost objects. This method is a potential solution to the problem of allocating fixed overheads and it's effective when short-term decisions are required.

Since 1980s, the appearance of advanced manufacturing environment has made enormous impact on the traditional cost accounting system. The primary failures of traditional costing systems are their inability to provide useful feedback about the costs and indeed most of them allocate overhead costs. In the context of decision making, inaccurate costs may lead to incorrect decisions, such as the production of

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unprofitable products and the non-production of profitable ones (Drury and Tayles 1995, Kaplan and Cooper 1998). In order to reduce the inaccuracies experienced by traditional costing systems, Activity-Based Costing (ABC) has become more popular in cost accounting¹.

ABC is a cost accounting system that identifies activities in an organization and assigns the cost of each activity resource to all products and services according to the actual consumption of each. The ABC process is capable to incorporate both physical measures and causal principles in the cost accounting system. The basic idea of ABC is to allocate costs to operations through the various activities in place that can be measured by cost drivers. Applying activity based costing brings different benefits for different organizations. According to the specifications of the system, we can say that putting the system in place would be effective in organizations with a complex and Non-uniform structure of activities, products, and customers. (Petrik, 2007) describes organizations with the most to gain from ABC implementation as:

- Those with a high frequency of different cost objects,
- Those with a large portion of indirect and supporting costs,
- Those with a great number of processes and activities.

1.1 Cost Driver Selection Strategies

Institutions have considerable discretion to choose which cost drivers to use for cost pool. Careful selection of cost driver fitness is important if a managerial costing system is to achieve its goal of enabling cost management. Cost drivers establish the basis upon which costs are allocated and therefore, are fundamental to any cost model and thus, cost models should use the best available “cost drivers”. The best available cost driver is the one that most closely and accurately approximates the way the cost is spent and for which the source data is available. Sensitivity analysisⁱⁱ can be carried out to inform manager, the impact of the different cost drivers on key cost pools. According to (Cooper 1989, Cooper 1989 a) the type of selected cost drivers changes the number of drivers required to achieve a desired level of accuracy. An increase in the number of cost drivers decreases the danger of using just one cost driver for one cost pool. This is expected to be indicative of an increase in accuracy, because a higher number of cost drivers are likely to represent quantities of resources consumed by individual products.

1.2 Cost Allocation Problem

(Porter and Millar 1985) classified a full value chain as nine interrelated primary and support activities. The first of these primary activities can be related to actions which an organization performs to satisfy the external demands, while secondary activities are conducted to serve the needs of internal ‘customers’. If a company carries out a sophisticated cost accounting system, the costs of secondary activities are usually gathered. The costs of these activities consume large portions of a company’s costs. How to deal with this group of costs is what we want to answer in this paper. Costs attributed to support departments, use cost drivers to allocate their costs to other support departments as well as operational departments. In this respect, the art and the ability of designing an ABC system can be viewed as making two separate but interrelated decisions, the number of cost drivers needed and which cost drivers to use (Babad and Balachandran 1993).

Increasing the number of activity cost pools in an ABC system probably increases the measurement accuracy of individual activity cost pools. Using high number of cost pools is expected to reduce the probability of costs being averaged across cost pools and to better represent the consumption of cost pool resources by products. This would be indicative of a higher level of sophistication. Even if companies would like to have sophisticated product costing systems however, there is a trade-off between the sophistication, and the running costs and understand ability of the system (Yoshikawa, Innes et al. 1989, Cooper 1990, Babad and Balachandran 1993, Homburg 2001). Historically, there have been three alternative methods for allocating support department costs to each other: 1) Direct Method 2) Step-Down Method and 3) Reciprocal Method. Cooper and Kaplan describe these methods as following:

- The direct method, ignores all of the interactions between support departments,
- The step-down method, ignores some of the interactions between support departments,
- The reciprocal method, which captures all of the interactions.

1.2.1 Reciprocal Allocation (RA) Method

Reciprocal allocation method allocates costs by recognizing that the support departments provide services to each other as well as to the production department's jobs, or project. The reciprocal method theoretically is the most acceptable method because it fully recognizes the mutual services provided among all departments, regardless of whether those departments are operating or support departments. It uses simultaneous equations to reallocate support department costs to each other and to operational departments. Solving this system of equations requires relatively complex set of iterative calculations. These reciprocated costs include not only the direct costs of the support department but also the costs allocated to it from the other support departments. (Kaplan 1973) and some others (Churchill 1964, Manes 1965) have worked out the mathematics of the more general reciprocal method solution using matrix algebra by showing that the method can be modeled as a form of a Leontief input-output economic model.

In this research we have used a mathematical model to solve the plurality of the relation between cost drivers and cost pool. We first define the cost allocation using a one-by-one relation between cost pools and cost drivers (Fig. 1). In the later part of paper we present a method for modeling multilateral relations between cost pools and cost drivers (Fig. 2). We did this without combining the representative cost drivers of specific support department into a single cost driver. These multilateral relations will lead to an over determined linear system (number of linear equations will be more than unknowns). We apply Least Square (LS) method which is a well-known method for solving over determined systems. Finally, in order to accomplish such a cost allocation process we have presented a case study with hypothetical data to portray the probable differences between RA method LS method.

2. Literature Review

In the 1980's much criticisms were raised regarding the ability of traditional cost accounting to provide relevant and accurate information for managers. During that period, ABC has emerged as one of the management accounting tools that recognizes such concern (Maelah and Ibrahim 2007). Since then ABC has gained its

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popularity and has received substantial attention from various departments including the academicians, and industries. ABC was initially developed due to the evident increase in overhead costs in Manufacturing Firms, sourcing many of the traditional costing inaccuracies; (Hussain and Gunasekaran 2001, Swenson and Barney 2001).

Numerous studies have noted that the use of the applicability of ABC to all organizations in general is attributed to the universal existence of activities (Kennedy and Affleck-Graves 2001). As a result, the utilization of ABC has been evident in areas such as database marketing (Doyle 2002), the financial industry (Innes and Mitchell 1995, Dodd, Lavelle et al. 2002) the healthcare industry (Lee and Nefcy 1997, West and West 1997) telecommunications, transport, wholesale and distribution and information services sectors (Kennedy and Affleck-Graves 2001). ABC in the manufacturing sector is still predominant);(Clarke and Mullins 2001);(Johnson 2002). The problem with research into information systems in general, and the sophistication of costing systems in particular is that in the context of information economics, system users are unaffected by sophistication (see Blackwell 1953; Marschak and Radner1972; McGuire 1972).

(Drury and Tayles 2005) identified a product costing system with high level of sophistication as consisting of many cost pools and many cost drivers including volume- and non-volume-based cost drivers transaction, duration, and intensity cost drivers. They argued that sophistication will be affected by the extent to which different cost drivers are used, such as volume-level, batch-level, and product sustaining cost drivers, with sophistication increasing with the use of non-volume-level cost drivers. In addition, they stated that sophistication is also dependent on whether transaction, duration, or intensity cost drivers are used. (Drury and Tayles 2005) subsequently measured sophistication using a combination of the number of cost pools and cost drivers used to allocate and assign overhead costs into product costs in order to produce a subjective 15-point sophistication scale, from a least sophisticated system score of 2 to a most sophisticated system score of 16. (Abernethy, Lillis et al. 2001) defined sophistication in a similar way to (Drury and Tayles 2005) with this distinguish that they made a distinction between the type and nature of cost pools.

(Kaplan and Anderson 2007) proposes a more accurate and efficient cost modelling principle called Time-Driven Activity Based Costing (TD-ABC) that assigns resources (e.g. all costs of a customer service department) directly to cost objects (e.g. order handling). This is done to achieve a simple cost rate measure based on time consumption. (Lechner, Klingebiel et al.) proposes the method Variety-driven Activity-based Costing (VD-ABC) to quantify the impact from adding or removing product variants in automotive logistics, based on the use of hypothetical zero-variant scenarios. This is an expansion of the TD-ABC framework allowing for the calculation of incremental complexity costs associated with variants in different logistical operations. (Zhang and Tseng 2007) propose a modelling approach to analyse cost implication of product variety in mass customization by bridging product variety with process variety. This is done by identifying cost drivers within the product design, and the method is confined to include manufacturing costs.

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$$\mathbf{Z}_{(r \times 1)} = \mathbf{P}_{(r \times s)} \mathbf{U}_{(s \times 1)} - \mathbf{V}_{(r \times s)} \times \mathbf{U}_{(s \times 1)} = (\mathbf{P}_{(r \times s)} - \mathbf{V}_{(r \times s)}) \mathbf{U}_{(s \times 1)} = \mathbf{A}_{(r \times s)} \mathbf{U}_{(s \times 1)}$$

$$\mathbf{A}_{(r \times s)} = \mathbf{P}_{(r \times s)} - \mathbf{V}_{(r \times s)} \quad (4) \quad \Rightarrow \mathbf{Z}_{(r \times 1)} = \mathbf{A}_{(r \times s)} \mathbf{U}_{(s \times 1)} \quad (5)$$

For the case that the number of equations is equal to the number of unknowns ($r = s$), matrix $\mathbf{A}_{(r \times s)}$ is an invertible matrix and $\mathbf{U}_{(r \times s)}$ will be defined with:

$$\mathbf{U}_{(s \times 1)} = \mathbf{A}_{(r \times s)}^{-1} \times \mathbf{Z}_{(r \times 1)} \quad (6)$$

For the case that there are at least more than one cost driver for one of the cost pools, we will have a linear system with " r " equations and " s " unknowns. Number of unknowns " s " is always equal to the number of cost pools. Number of equations " r " can be defined with considering all possible choices of cost driver for each cost pool. Assume there are w_j different choices for cost driver " j ". In this situation all possible choices for " s " cost pools will be $w_1 \times w_2 \dots \times w_s$ and consequently total number of equations " r " will be:

$$r = s \times [w_1 \times w_2 \dots \times w_s] = s \times \prod_{j=1}^{j=s} w_j \quad (7)$$

In mathematics, when ($r > s$), the system of linear Equations (5) is called *over determined*. The solution of over determined systems usually is estimated by the method called Least Squares (LS). This method was first described by Carl Friedrich Gauss around 1794. Term "Least squares" corresponds to the fact that the overall solution will minimize the sum of the squares of the errors made in the results of every single equation. In over determined system which ($r > s$), either side of the Equation (5) will be multiplied by \mathbf{A}^T which gives,

$$\mathbf{A}_{(s \times r)}^T \mathbf{Z}_{(r \times 1)} = \mathbf{A}_{(s \times r)}^T \mathbf{A}_{(r \times s)} \times \mathbf{U}_{(s \times 1)} \quad (8)$$

In Equation(8), $[\mathbf{A}_{(s \times r)}^T \mathbf{A}_{(r \times s)}]$ is a square and invertible matrix which will be used to solve the over determined system. Multiplying either side of the above equation by $[\mathbf{A}_{(s \times r)}^T \mathbf{A}_{(r \times s)}]^{-1}$ Gives the final estimated values of unknown:

$$\mathbf{U}_{(s \times 1)} = [\mathbf{A}_{(s \times r)}^T \mathbf{A}_{(r \times s)}]^{-1} \mathbf{A}_{(s \times r)}^T \mathbf{Z}_{(r \times 1)} \quad (9)$$

Testing the new survey

To better understand these concepts, we analyse a simple *case study* where, there are more than one cost driver for each support department. Suppose we have a company with two support departments ($\mathbf{u}_1, \mathbf{u}_2$) and two operational departments ($\mathbf{u}_3, \mathbf{u}_4$). The problem is to allocate the costs of these departments to each other considering all internal relations between them. Table 1 shows the parameters of the cost drivers (\bar{v}_{ij}^n) and primary costs of cost pool (\mathbf{z}_i).

Table 1: Hypothetical Cost Driver Parameters (\bar{v}_{ij}^n)

i	\bar{v}_{i1}^1	\bar{v}_{i1}^2	\bar{v}_{i2}^1	\bar{v}_{i2}^2	\bar{v}_{i2}^3	z_i in \$
$i = 1$	350	800	2400	160	110	45000
$i = 2$	150	25	50	50	5	10000
$i = 3$	100	35	1600	40	40	30000
$i = 4$	250	40	1000	50	50	20000

In this company operational departments (u_3, u_4) don't provide service to support departments (u_1, u_2) so we don't allocate cost of them (u_3, u_4) to the other departments. In other word, the cost allocation ratio for these departments will be zero ($v_{i3}^n = v_{i4}^n = 0$ for $i = 1, \dots, 4$). Using Equation (1) and the information presented in Table (1) we can determine the cost allocation ratio for each cost driver. Table 2 shows the results obtained by this fashion.

Table 2: Cost allocation Ratio (V_{ij}^n) for Least Squares (LS) method

i	v_{i1}^1	v_{i1}^2	v_{i2}^1	v_{i2}^2	v_{i2}^3
$i = 1$	0	0	0.48	0.64	0.55
$i = 2$	0.30	0.25	0	0	0
$i = 3$	0.20	0.35	0.32	0.16	0.20
$i = 4$	0.50	0.40	0.20	0.20	0.25

So far we have specified the cost pools; cost drivers, primary cost of each cost pool and we have also calculated cost driver ratios. Having these data, we can allocate the cost of cost pools using reciprocal method (Section 3.1) and least square method (Section 3.2). In section 3.1 we will use only most probable choice as cost driver (conventional method). In section 3.2 we will use all possible choices for the cost driver.

3.1 Cost Allocation using Reciprocal Allocation Method (RA)

In this method management of company is in force to use only one cost driver for each cost pool. We use v_{i1}^1 and v_{i2}^1 (as the most probable choices for the cost drivers) to allocate cost of u_1 and u_2 departments respectively. Figure 1 shows (one by one) relation between cost drivers and cost pools.

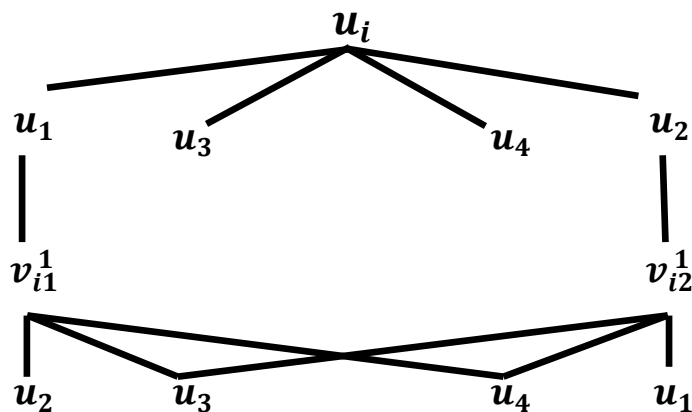


Figure1: Cost allocation with one by one-relation between cost drivers and cost pools

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In order to define the final cost of cost pools, we should solve the cost allocation equations (equation 2). Using equation (7) we determine the number of unknown parameters "s" and number of equations "r" will be:

$$s = \# \text{ of cost pools} = 4 \xrightarrow{\text{Eq. (7)}} r = s \times \prod_{j=1}^{j=s} w_j = 4 \times (1 \times 1 \times 1 \times 1) = 4$$

$$\begin{cases} u_1 = 0.48u_2 + 45000 \\ u_2 = 0.3u_1 + 10000 \\ u_3 = 0.2u_1 + 0.32u_2 + 30000 \\ u_4 = 0.5u_1 + 0.2u_2 + 20000 \end{cases} \xrightarrow{\text{matrix form}} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 0 & 0.48 & 0 & 0 \\ 0.30 & 0 & 0 & 0 \\ 0.20 & 0.32 & 0 & 0 \\ 0.50 & 0.20 & 0 & 0 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} + \begin{bmatrix} 45000 \\ 10000 \\ 30000 \\ 20000 \end{bmatrix}$$

Above matrix can be presented in the standard form of (Equation 6)

$$\begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 1 & -0.48 & 0 & 0 \\ -0.30 & 1 & 0 & 0 \\ -0.20 & -0.32 & 1 & 0 \\ -0.50 & -0.20 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} 45000 \\ 10000 \\ 30000 \\ 20000 \end{bmatrix} = \begin{bmatrix} 58180 \\ 27450 \\ 50420 \\ 54580 \end{bmatrix}$$

Table 3 shows the primary costs of cost pools z_i , final costs of cost pools u_i , and the received costs of cost pools ($u_i - z_i$),

Table 3: Primary cost, Cost received and Final cost using (RA) method

i	Primary Costs (z_i in \$)	Final costs (u_i in \$)	Cost received ($u_i - z_i$ in \$)
$i = 1$	45000	58,180	13,180
$i = 2$	10000	27,450	17,450
$i = 3$	30000	50,420	20,420
$i = 4$	20000	54,580	34,580

3.2 Cost Allocation using Least Squares Method (LS)

The main assumption in section 3.1 was that "cost drivers and cost pools have a one by one relation". To the best knowledge of us previous literatures, allocate the costs based on this assumption. As previously described, in this section we will use an allocation method in which, different cost drivers are used to allocate the cost of one cost pool. Using different cost drivers, mathematically gives rise to the number of equations needed to solve the allocation problem (over determined systems). In this section for cost allocation of cost pool u_1 , we use both of cost drivers (V_{i1}^1, V_{i1}^2) simultaneously. Also for cost allocation of cost pool u_2 , three cost drivers ($V_{i2}^1, V_{i2}^2, V_{i2}^3$) should simultaneously be used. Figure 2 shows the relations between cost drivers and cost pools. Now we can define the Number of unknowns "s" and number of equations "r" by using equation (7):

$$s = \# \text{ of cost pools} = 4 \xrightarrow{\text{Eq. 7}} r = 4 \times \prod_{j=1}^{j=4} w_j = 4 \times 2 \times 3 \times 1 \times 1 = 24$$

Appendix A shows the cost allocation ratio in the condition that there is a multilateral relation between cost drivers and cost pools. So that different choices of cost drivers

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are chosen for each cost pool. These ratios form the cost allocation ratio matrix $V_{(24 \times 4)}$.

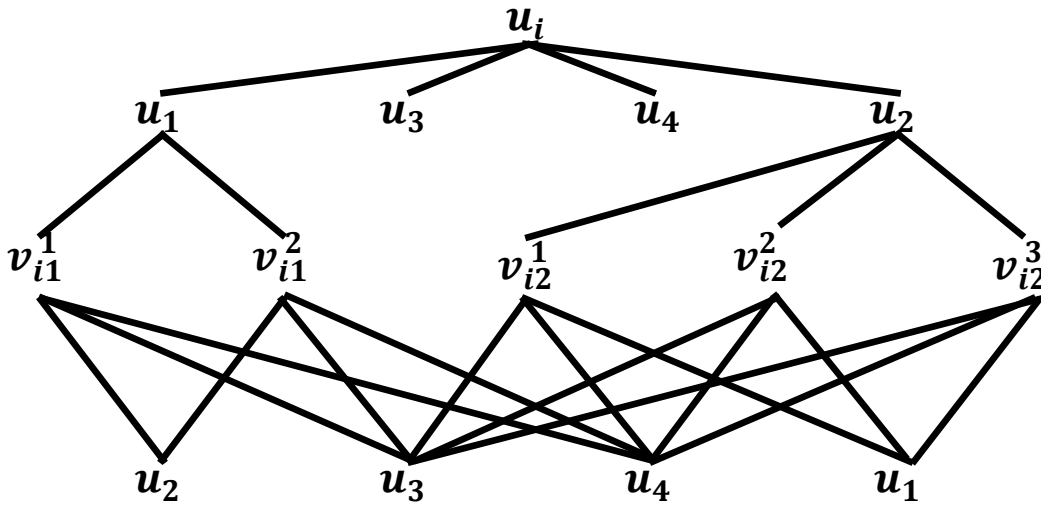


Figure 2: Cost Allocation with Multilateral Relations between Cost Drivers and Cost Pools

$$\text{Finally } \xrightarrow{Eq.9} U_{(4 \times 1)} = [A_{(4 \times 24)}^T A_{(4 \times 24)}]^{-1} A_{(24 \times 4)}^T Z_{(24 \times 1)} \rightarrow U_{(4 \times 1)} = \begin{bmatrix} 58,490 \\ 25,460 \\ 51,856 \\ 51,840 \end{bmatrix}$$

Table 4 shows the primary costs of cost pools (z_i), final costs of cost pools (u_i), and the received costs of cost pools ($u_i - z_i$).

Table 4: Results from Cost Allocations in (LS) Method

i	Primary Costs (z_i in \$)	Final costs (u_i in \$)	Cost received ($u_i - z_i$ in \$)
$i = 1$	45000	58,490	13,490
$i = 2$	10000	25,460	15,460
$i = 3$	30000	51,856	21,856
$i = 4$	20000	51,840	31,840

To compare the results obtained by RA method and LS methods we present them in Table 5 together. These results show us that we have different final (u_i) cost and cost received ($u_i - z_i$) in all four cost pool. This differentiation is especially obvious in three of them ($i = 2, 3$ and 4).

Table 5: Conclusions and Consequences

i	Primary Costs (z_i in \$)	Final costs (u_i in \$)		Cost received ($u_i - z_i$ in \$)		Difference (in \$)
		(RA) Method	(LS) Method	(RA) Method	(LS) Method	
$i = 1$	45000	58,180	58,490	13,180	13,490	-310
$i = 2$	10000	27,450	25,460	17,450	15,460	1,990
$i = 3$	30000	50,420	51,856	20,420	21,856	-1,436
$i = 4$	20000	54,580	51,840	34,580	31,840	2,740

4. The Findings

The novelty of our study is that even in the case of large companies, managers can use more than one cost driver simultaneously based on their importance to allocate the cost of specific support department. We believe solving over determined system (section 3.2) gives better results than RA method (section 3.1). This is because; the management is able to use all possible cost drivers and not only the most probable one. Increase in the number of cost drivers decreases the danger of overweighting just one (the most probable) cost driver for one cost pool. Using different cost drivers simultaneously increases the number of cost allocation equations which gives an over determined system. In this paper over determined system is solved by the method called Least Squares. We can find from Table 5 that, RA and LS method allocate costs of support departments with different way. Different cost drivers should have contribution in cost allocation and LS method helps managements to use these cost drivers based on their importance simultaneously which we found it providing better results than RA method.

5. Summary and Conclusion

Basic, consistent and reliable cost information is necessary for any organization, from its pricing policies to its product designs and performance reviews. This is because inaccurate costs may lead to incorrect decisions, such as the production of unprofitable products and the non-production of profitable ones. The support departments of enterprises provide a wide range of support activities necessary for effectively conducting primary activities and for the enterprise as the whole. In such circumstance the problem is allocating the costs of support departments to each other considering all internal relations between them. The research on cost driver has its significant theoretical meaning as well as enormous applicative value in cost allocation studies. Institutions have considerable discretion to choose which cost drivers to use for which cost pool. A wide range of cost drivers could be used but it is important to find a new way to avoid confusion over the two or several sets of cost drivers. In this research we have presented a mathematical cost allocation model to solve the plurality presented between cost driver and cost pool. To this end we suggest to the managers and other users of costing systems to use LS model.

The new method presented in this paper is applicable in industries whose cost pools follow more than a single cause- and- effect relation between cost driver and cost pool, and overhead costs form a main part of costs of products or services. The main drawback of proposed method is that considering all possible cost drivers in large organizations can increase the number of equations and the complexity of the cost allocation. Even in some cases it may need more processing time for matrix inversion (Equation 9). However, in some applications, it is important for management to employ an accurate but possibly sophisticated costing system. If the costs of increasing sophistication are greater than the benefits of increasing that sophistication, then a more sophisticated system should not be implemented (Cooper 1988). Our Suggestions for future researches is to studying and recognizing industries in which the new method (LS) has enormous applicative value, and implementation of such methods, considering the cost benefit of information gathering, is possible and useful for decision making. In our future work we would like to first analyse the importance of different cost drivers and then we will use Weighed Least Square (WLS) to solve the over determined allocation problem.

Endnotes

i Cost accounting is an essential element of financial management that generates information about the costs of the products. Cost accounting first measure and record these costs individually, then compare input results to output or actual results to aid company management in measuring financial performance.

ii Sensitivity analysis, or post optimality analysis, is the study of how sensitive solutions are at the impact of parameter changes. Sensitivity analysis is concerned with understanding how changes in the model input data's influence the outputs. The results of sensitivity analysis establish upper and lower bounds for input parameter values within which they can vary without causing violent changes in the current optimal solution.

iii In mathematics, a system of linear equation is considered over determined if there are more equations than unknowns. The solution of over determined systems usually is estimated by the method called Least Squares (LS). This method was first described by Carl Friedrich Gauss around 1794. Term "Least squares" corresponds to the fact that the overall solution will minimize the sum of the squares of the errors made in the results of every single equation. The implementation of LS method in ABC is a collective process and brings with it new cost calculation rules.

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Appendix

Appendix A: Cost Allocation Ratios (V_{ij}^n) in LS

Method			
V_{i1}^1	V_{i2}^1	V_{i3}^1	V_{i4}^1
0	0.48	0	0
0.30	0	0	0
0.20	0.32	0	0
0.50	0.20	0	0
<hr/>			
V_{i1}^1	V_{i2}^2	V_{i3}^1	V_{i4}^1
0	0.64	0	0
0.30	0	0	0
0.20	0.16	0	0
0.50	0.20	0	0
<hr/>			
V_{i1}^1	V_{i2}^3	V_{i3}^1	V_{i4}^1
0	0.55	0	0
0.30	0	0	0
0.20	0.20	0	0
0.50	0.25	0	0
<hr/>			
V_{i1}^2	V_{i2}^1	V_{i3}^1	V_{i4}^1
0	0.48	0	0
0.25	0	0	0
0.35	0.32	0	0
0.40	0.20	0	0
<hr/>			
V_{i1}^2	V_{i2}^2	V_{i3}^1	V_{i4}^1
0	0.64	0	0
0.25	0	0	0
0.35	0.16	0	0
0.40	0.20	0	0
<hr/>			
V_{i1}^2	V_{i2}^3	V_{i3}^1	V_{i4}^1
0	0.55	0	0
0.25	0	0	0
0.35	0.20	0	0
0.40	0.25	0	0

Appendix B: Simultaneous Equations of LS Method In Matrix Format (Eq. 3)

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} = \begin{bmatrix} 0 & 0.48 & 0 & 0 \\ 0.30 & 0 & 0 & 0 \\ 0.20 & 0.32 & 0 & 0 \\ 0.50 & 0.20 & 0 & 0 \\ 0 & 0.64 & 0 & 0 \\ 0.30 & 0 & 0 & 0 \\ 0.20 & 0.16 & 0 & 0 \\ 0.50 & 0.20 & 0 & 0 \\ 0 & 0.55 & 0 & 0 \\ 0.30 & 0 & 0 & 0 \\ 0.20 & 0.20 & 0 & 0 \\ 0.50 & 0.25 & 0 & 0 \\ 0 & 0.48 & 0 & 0 \\ 0.25 & 0 & 0 & 0 \\ 0.35 & 0.32 & 0 & 0 \\ 0.40 & 0.20 & 0 & 0 \\ 0 & 0.64 & 0 & 0 \\ 0.25 & 1 & 0 & 0 \\ 0.35 & 0.16 & 0 & 0 \\ 0.40 & 0.20 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0.55 & 0 & 0 \\ 0.25 & 1 & 0 & 0 \\ 0.35 & 0.20 & 0 & 0 \\ 0.40 & 0.25 & 0 & 0 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{bmatrix} + \begin{bmatrix} 45000 \\ 10000 \\ 30000 \\ 20000 \\ 45000 \\ 10000 \\ 30000 \\ 20000 \\ 45000 \\ 10000 \\ 30000 \\ 20000 \\ 45000 \\ 10000 \\ 30000 \\ 20000 \\ 45000 \\ 10000 \\ 30000 \\ 20000 \end{bmatrix}$$