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Comparison between the Mix-Based Costing and the Activity-Based Costing Methods in the Costing of Construction Projects

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After bibliographic research on costing methods in civil construction, and a presentation of the mix-based costing method, as well as an application of the activity-based costing method in the costing of civil construction projects based on other authors, a possible application of the mix-based costing was sought. This method allows the distribution of costs and indirect expenses to products without the subjectivities and uncertainties typical of traditional apportionment, by means of analyses of different production scenarios. The main objective of this article is to compare the results obtained from activity-based costing and mix-based costing in the costing of civil construction works.

Introduction

The major drawback of all costing methods is that they induce subjective and arbitrary elements when dealing with the apportionment of indirect costs. In civil construction, this becomes even more complex, since the cost object can present different delimitations, thus entailing significantly different classifications of costs/expenses. For example, the following can all be considered as cost objects: construction processes, the construction of a particular building, or even a set of works, that is, the costing of the entire project.

The objective of this article is to compare the mix-based costing (MIXBC) and the activity-based costing (ABC) methods, taking as example the costing of civil construction projects. Another aim is to present the application of the MIXBC method, demonstrating the steps of the process, the adequate approach to the scenario analysis, and the feasibility of this method for the costing of products.

The methodology adopted was bibliographical research, associated with the experience of the authors on the theme, which made it possible to analyze the main characteristics of costing in civil construction. Starting with results presented by earlier works on the application of the ABC method to civil construction projects, a practical application of the MIXBC method was carried out, followed by a comparison of the results obtained by both methods.

The benefits resulting from this analysis include a better understanding of the use of the MIXBC method by means of a practical application. This evidences the advantages of the method in the reduction of the arbitrary and subjective elements caused by traditional arbitrary apportionment, thus contributing to more efficient costing and to more profitable production strategies.

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Characteristics and Difficulties of Costing in Civil Construction

Martins (2010) explains that *costing* means *cost appropriation*. To this it can be added that a costing system can be regarded as the whole structure necessary to accomplish the task, including the philosophy and the costing method. In this sense, the costing system can be considered as defining and applying a costing philosophy/method to a particular organizational reality. This encompasses the structuring of the measurements necessary to the production process, the definition of responsibilities, data collection, data treatment, recording of data generated, the decision of whether or not to use computer systems, etc.

Different costing methods may result in significantly different interpretations, particularly as regards product profitability (Di Gregorio & Soares, 2012). This is a crucial parameter in decision making of production volume (the amount of products to be manufactured in a certain period of time) and of business strategies. The costing system should not only be functional, but should also provide a good cost-benefit relation, since the measurement of certain costs can become economically unfeasible.

Civil construction, when compared with other productive sectors, is widely mentioned as the sector which presents the least technological evolution (Soares & Chinelli, 1998). A comparison between the characteristics of the manufacturing industry and civil construction is shown in Table 1.

This is mainly due to its typical characteristics. According to Matteson (in Rocha et al., 1999), the civil construction business presents certain peculiarities, particularly the large scope of its activities, which distinguishes it from other businesses. Some of these particularities are:

- Production essentially by order.
- Frequent periods in which personnel and machinery remain idle, sometimes for indefinite periods of time, waiting for (new) works.
- Works are at the same time the product of the business (source of revenue) and an independent functional structure within the business, as if there were an overlapping of businesses.
- Bids made by the commercial area of the business are subject to failure. This occurs in civil construction businesses that take part in both public and private bidding processes, since in both cases the success rate of bids is low.

As regards civil construction, Isatto (2003) points out that the information provided by traditional accounting systems contributes little to process management. Thus, managers adopt alternative control systems, such as budget and parallel cost controls, especially those based on unit production standard costs. According to the same author, building contractors and companies adopt monthly and annual financing accounting systems to record their profits and losses. This does not make sense since the cycle of their products exceeds a year.

It becomes evident then that adequate cost management is directly associated with an understanding and a control of the production process of that particular building construction. Therefore, management per process is the most efficient way to understand how costs are distributed along the activities that make up the process. It allows a vision of the flow aligned with project management, which is derived from an activity-centered approach (Kim & Ballard, 2001).

There is yet another aspect of great importance in civil construction costing: the way indirect production costs and expenses are assigned to cost objects. The delimitation of the cost object is mainly ruled by the focus one wishes to give to cost control, and later to the viewpoint from which one wishes to examine the results. In the case of civil construction,

TABLE 1 Comparison between characteristics of manufacturing and civil construction industries

	MANUFACTURING INDUSTRY	CIVIL CONSTRUCTION INDUSTRY
PRODUCT	• Almost always the same	• Always different
	• Movables	• Immovables and large scale
	• Small unit value	• Large unit value
MANUFACTURING SITE	• Only one site (factory)	• Different and temporary work sites (building sites)
	• Fixed job positions and product in movement	• Components converging towards a fixed product
	• Similar arrangements, making it possible to set general rules	• Different arrangements, specific to each construction project
PRODUCTION	• Mechanized production	• Predominantly craft production
	• Assembly line	• Production in diverse situations
	• Repetitive operations	• Operations alternate over the course of time and the evolution of the works
	• Problems in production repeated along the line	• Problems always different according to space and time
INPUT	• Standardized components	• Lack of standardization
	• Skilled labor force	• Unskilled labor force

Source: Trajano (in Soares & Chinelli, 1998).

for example, there are three main types of cost object: *the project, the work itself*, and the *construction process*.

Activity-Based Costing (ABC) Method

ABC costing came from the need to reduce the distortions caused by arbitrary and subjective elements in the apportionment of indirect costs to products and services. Martins (2010) points out that these distortions are influenced by two main factors: proportion of total indirect costs and product line diversification. The concept of cost distribution presented by ABC does not refer to "apportionment" strictly speaking, but rather to "tracking."

Referring to ABC, Beuren et al. (2003), quoting Kaplan and Cooper, stated that "an activity-based costing system provides businesses with an economic map of their operations, which reveals the existing and the estimated costs of activities and processes of businesses. These costs, in turn, reveal the cost and the profitability for each product, service, client and operational unit." The same authors, quoting Padoveze, stress that activity-based costing first assigns costs to activities (by means of resources consumed by these activities) and then to products (by means of the activities "consumed" by these).

The fundamental concept for ABC is: products consume activities, activities consume resources.

Binato and Estrada (2002) adopt an interesting activity-based costing approach to civil construction, in which a cost driver is proposed, one that combines complexity, construction time, and size of the building. This cost driver allows indirect costs to be apportioned to the apartments. Direct costs are proportionally distributed according to the area of each apartment. It can be noticed, however, that the cost object is "the project as a whole" and not the apartments. Thus, costs initially assigned to the project have always been somehow indirectly apportioned so that the costs for each apartment could be reached. It is possible to adopt units (apartments) as cost objects, but without greater relevance to cost management.

On the other hand, Kim and Ballard (2001), as well as Schmidt and Zornita (2001) perform cost analyses using the processes of rebar and forms, and internal plasterwork, respectively, as basis for the analysis. This is evidently a use of ABC (activity-based costing), in which the cost object is "the process."

Rocha et al. (1999), analyzing seven building companies, adopted an ABC approach, in which costs were assigned according to the type of construction work being undertaken, to wit: *paving, sanitation*, and *buildings.* This classification may have tried to create a "symbolic product having an annual cycle," understood as the set of works of the same type, whether finished or unfinished, which fall into a certain period of time, to which direct costs, indirect costs, and expenses are assigned, and which constitute a cost object analogous to a "project." The MIXBC shall be used on this case.

Mix-Based Costing (MIXBC) Method

What It Is

MIXBC is a costing method that allows the reduction of uncertainties caused by arbitrary apportionment of indirect costs and expenses in product cost.

The MIXBC method was built on the analyses of the product mix (rather than on that of products individually), and also on the hypothesis that the absence of a certain product in the mix provides clues as to the degree of utilization of shared costs (costs shared by one or more products, usually indirect) by that particular absent product. The method can also be called absence costing or inference costing.

MIXBC allows costs and indirect shared expenses—which cannot be actually separated for each product—to be treated in a mathematical and coherent way. This contrasts with the other methods, which usually apportion or track expenses.

In MIXBC, the uncertainties are calculated by a process of cost inference, based on the exclusive production (only the product analyzed is produced) and excludent production (only the product analyzed is not produced) scenarios.

As with any other costing method, it is also true that the complexity of the costing operation may increase significantly according to the number of products analyzed (the number of scenario analyses required to a mix of "N" products is $2N + 1$). However, one of the advantages of the MIXBC method is that it can guide a team of multidisciplinary professionals through even an eventual complex process of costing.

The success of MIXBC method is based on the coherence of the analysis performed by the multidisciplinary team, that aim to understand which resources (or group of resources) are required to each scenario for the production process. It is important to highlight that the performance of the team may be strongly improved by the work of a skilled facilitator.

The first and main objective of the analysis is to solve the problem of allocation of the shared resources (and thus the costs and expenses) to the products and not to make judgment of how the allocation can be arranged to improve the results. However, the method can be used to find out the most profitable products in the present product MIX (Di Gregorio & Soares, 2012), and what makes it a valuable tool that can work together with value focused thinking (VFT) strategies and then contribute to improve the results.

Another advantage of the MIXBC method is that it does not demand the previous classification of costs and expenses in direct/indirect. They can be automatically allocated to the products (independently of their classification) as an output of the method, what makes it easily programmable. Although, applying the method only to indirect costs and expenses may reduce significantly the amount of data to be analyzed.

Besides the exposed, contrariwise to the ABC method, the MIXBC does not require the allocation of the resources to the activities, but directly to the products in a more subjective and generic way, which may make it less bureaucratic (but not necessarily less accurate).

The Distribution of Fixed Indirect Costs

Let us examine the hypothetical case of a business that produces three products (exemplified as Alpha, Beta, Gamma), which have total fixed costs (CF) and fixed expenses (DF).

Thus, the total fixed cost (CF) of the product mix (Alpha, Beta, and Gamma) can be written as (see Figure 1):

$$CF_{ALPHA,BETA,GAMMA} = CF_{MIX} = CF_{I} + CF_{II} + CF_{III} + CF_{IV} + CF_{V} + CF_{VI} + CF_{VII}. \quad (1)$$

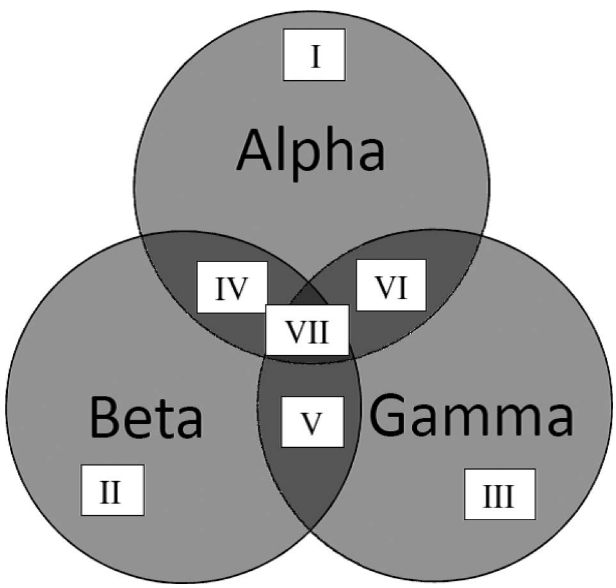

FIGURE 1 Graphic representation of the universe of fixed costs for a business which produces products Alpha, Beta, and Gamma.

Considering the situation in which product Alpha is discontinued by the business and its production is not substituted by any other product, the new distribution of fixed costs are shown in Figure 2.

The total fixed cost for the new product mix (only Beta and Gamma, without the participation of Alpha) can be written as:

$$CF_{MIX-ALPHA} = CF_{II} + CF_{III} + CF_{IV} + CF_{V} + CF_{VI} + CF_{VII}. \quad (2)$$

Substituting Equation (2) in Equation (1), we find:

$$CF_{MIX} = CF_{I} + CF_{MIX-ALPHA}. \quad (3)$$

This can also be considered as the *Minimum Fixed Cost* that can be ascribed to product Alpha:

$$CF_{ALPHA,MIN} = CF_{I}. \quad (4)$$

On the other hand, if there were only product Alpha (without the other mix products), the fixed costs related to it would be maximum and would be calculated by:

$$CF_{ALPHA,MAX} = CF_{ALPHA} = CF_{I} + CF_{IV} + CF_{VI} + CF_{VII}. \quad (5)$$

Substituting Equation (4) in Equation (5), we find:

$$\Delta CF_{ALPHA} = CF_{ALPHA,MAX} - CF_{ALPHA,MIN} = CF_{IV} + CF_{VI} + CF_{VII}. \quad (6)$$

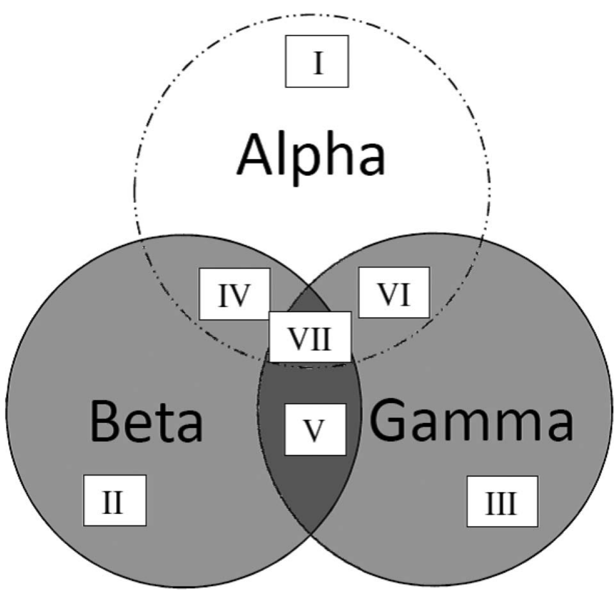

FIGURE 2 Graphic representation of the universe of fixed cots for a business which produces products Beta and Gamma.

in which the term, could be considered as the range of variation of fixed costs for product Alpha and it represents the extent of use of the mix structure by product Alpha, or the extent to which product Alpha depends on the mix structure.

The fixed cost of the structure shared by the product mix can be defined by:

$$CF_{COMP} = CF_{IV} + CF_{V} + CF_{VI} + CF_{VII}. \tag{7}$$

Applying the same reasoning and substituting in Equation (1), we find:

$$CF_{MIX} = CF_{ALPHA,MIN} + CF_{BETA,MIN} + CF_{GAMMA,MIN} + CF_{COMP}. \tag{8}$$

That is, the fixed cost of the structure shared by the mix can be determined by subtracting from the present situation the minimum fixed costs for each product (determined by the scenarios of absence of each one, sequentially).

$$\begin{aligned} CF_{COMP} = {} & CF_{MIX} - (CF_{MIX} - CF_{MIX-ALPHA}) \\ & - (CF_{MIX} - CF_{MIX-BETA}) - (CF_{MIX} - CF_{MIX-GAMMA}). \end{aligned} \tag{9}$$

Thus

$$CF_{COMP} = CF_{MIX-ALPHA} + CF_{MIX-BETA} + CF_{MIX-GAMMA} - 2CF_{MIX}. \tag{9a}$$

Generalizing for a mix of “N” products, we find:

$$CF_{COMP} = CF_{MIX-1} + CF_{MIX-2} + \cdots + CF_{MIX-N} - (N-1)CF_{MIX}. \tag{10}$$

As previously seen, the ranges of fixed costs for each product (show the utilization of the mix for each product, respectively. Thus, to define the degree of use of the mix for product I, based on costs (UC%), we find:

$$UC\%_i = \frac{\Delta CF_i}{CF_{COMP}} \times 100. \tag{11}$$

Thus, in order to define the participation of each product in the fixed cost of the mix (the amount each of them absorbs from the mix, when compared with the remaining products), it is necessary to normalize the UC% parameter, obtaining what was called factors of cost participation (FPCs), that is:

$$FPC_i = \frac{UC\%_i}{\sum_1^N UC\%_j} = \frac{\Delta CF_i}{\sum_1^N \Delta CF_j}. \tag{12}$$

Thus, the total fixed cost for a particular product in terms of its shared structure in the mix can be written as:

$$CF_i = CF_{i,MIN} + FPC_i * CF_{COMP}. \tag{13}$$

Checking Coherence

The situations in which the model loses its coherence may be due to misevaluation by the cost analyses team, or due to a degree of coherence that is not easily perceived by the team, thus inducing to error.

- ***Individual conditions:***
  - In the exclusive production scenario for product “i”, resources should not exceed amounts available in the mix.
  - In the excludent production scenarios for product “i”, resources should not exceed the amount available in the mix.
  - In the exclusive and excludent scenarios for product “i”, resources should not be lesser than the amount available in the mix.
  - For a certain product, the maximum resources should be greater than the minimum resources defined from the mix.
- ***Collective condition:*** Resources shared in the production mix should not be negative.

Applying the MIXBC Method to the Cost Object “Project”

The following guidelines were used to apply the MIXBC method:

a. Definition of cost object;
b. Mapping of resources considered indirect expenses and costs, and their corresponding expenditures;
c. Analysis of scenarios, in which the amounts of resources necessary to make up hypothetical situations of exclusive and excludent scenarios are identified;
d. Calculations required by the MIXBC method; and
e. Distribution of indirect costs and expenses to cost objects.

MIXBC will be applied to indirect costs and expenses in a way similar to that applied using ABC in the example presented by Rocha et al. (1999), which shall be used for comparison and analysis. In the example presented by these authors, the ABC method was applied to the costing of civil construction projects (Paving, Sanitation and Buildings), using activities typical of departments responsible for indirect costs (Engineering, Supplies, Human Resources, Accounting and Financial). In Table 2 one can note that the distribution of activity costs to products (in this case, the projects mentioned), also expressed as percentages.

These authors also mention the existence of indirect costs to which the ABC method was not applied. It was necessary to apportion these costs under two different categories: per revenues (Revenue) and per hours worked (W-h), as shown in Table 3.

In order to simulate costing using the MIXBC method, it shall be presumed that the data provided by ABC costing show approximately the real distribution of indirect costs. Thus, based on the costs of activities provided by ABC, we shall try to extract how resources were assigned to activities, using a reverse process and trying to return to the origins of ABC, since this information is not to be found in the article from where the example was taken. In fact, the origin of the data is not much relevant, since our aim is to prove that for any input data shared with the application of ABC the MIXBC shall lead to similar results in the tracking of indirect costs carried out by the former method. In other words, using the same input, a relatively similar output is expected to be found.

TABLE 2 Appropriation of costs according to drivers defined in the application of ABC method

	COST DISTRIBUTION IN PROJECTS						
ACTIVITIES	Pav.	%	San.	%	Build.	%	Total
Engineering Department							
Information gathering	39,529.64	42.42	31,059.00	33.33	22,588.36	24.24	93,177.00
Building documents	46,588.50	13.64	103,530.00	30.30	191,530.50	56.06	341,649.00
Planning of works	85,722.84	46.00	37,270.80	20.00	63,360.36	34.00	186,354.00
	171,840.98	**27.66**	**171,859.80**	**27.67**	**277,479.22**	**44.67**	**621,180.00**
Supplies Department							
Material receiving	3,183.04	15.56	8,184.96	40.00	9,094.40	44.44	20,462.40
Product storage	1,136.80	13.33	1,515.73	17.78	5,873.47	68.89	8,526.00
Product distribution	1,705.20	10.00	3,410.40	20.00	11,936.40	70.00	17,052.00
Price survey	5,115.60	20.00	8,526.00	33.33	11,936.40	46.67	25,578.00
Emission of orders	3,069.36	22.50	3,751.44	27.50	6,820.80	50.00	13,641.60
	14,210.00	**16.67**	**25,388.53**	**29.78**	**45,661.47**	**53.56**	**85,260.00**
Human Resources Department							
Candidate interviews	11,611.60	22.22	29,029.00	55.56	11,611.60	22.22	52,252.20
Recordkeeping	5,627.16	14.00	20,097.00	50.00	14,469.84	36.00	40,194.00
Payroll	42,624.33	18.60	127,873.00	55.81	58,608.46	25.58	229,105.80
Staff dismissal	13,398.00	16.67	24,116.40	30.00	42,873.60	53.33	80,388.00
	73,261.09	**18.23**	**201,115.40**	**50.04**	**127,563.50**	**31.74**	**401,940.00**
Accounting Department							
Recordkeeping	3,800.16	20.00	4,560.19	24.00	10,640.45	56.00	19,000.80
Trial balance	4,628.40	33.33	4,628.40	33.33	4,628.40	33.33	13,885.20
Balance sheet	1,218.00	33.33	1,218.00	33.33	1,218.00	33.33	3,654.00
	9,646.56	**26.40**	**10,406.59**	**28.48**	**16,486.85**	**45.12**	**36,540.00**
Financial Department							
$Invoices_I$	2,706.67	16.84	4,912.60	30.56	8,458.33	52.61	16,077.60
Collection	1,771.64	13.47	4,739.13	36.03	6,643.64	50.51	13,154.40
Preparation of duplicate invoices	3,118.08	17.78	5,651.52	32.22	8,769.60	50.00	17,539.20
Payments	3,377.92	17.78	6,22.48	32.22	9,500.40	50.00	19,000.80
Writing off invoices	1,299.20	17.78	2,354.80	32.22	3,654.00	50.00	7,308.00
	12,273.50	**16.79**	**23,780.53**	**32.54**	**37,025.97**	**50.66**	**73,080.00**

Source: Rocha et al. (1999).

TABLE 3 Apportionment of expenses, per revenue and per hours worked

TYPE OF EXPENSE	Total	Paving	Sanitation	Buildings
Apportionable costs and expenses (Revenue)	**882,000.00**	504,000.00	252,000.00	126,000.00
Apportionable costs and expenses (Hours worked)	**882,000.00**	164,093.02	492,279.07	225,627.91

Source: Rocha et al. (1999).

Using the cost spreadsheet for activities obtained with the ABC method shown in the example (per department), we sought to identify the resources that integrate each department, in order to reconstruct the original cost appropriation of the departmentalization.

After that, estimates for unit costs for each resource were made in line with market values. The amounts necessary for each resource to be consumed in the ABC method were also estimated. Adjustments were made so that costs of activities forecast would be close to costs presented by ABC and so that the total cost for each department would be identical to the one presented by ABC.

In order to illustrate this process, the results of operations for the Engineering department will now be presented. It should be noticed that the same procedure was repeated for the remaining departments, and also for the apportionable costs and expenses (see Table 4).

The next step was to apply the percentage of cost distribution of projects (calculated by ABC) to the amounts of the resources estimated, thus providing an idea of how projects "consume" resources. The objective of this simulation was to obtain a reference for the MIXBC analysis, based on amounts approximate to the ones that gave rise to the cost distribution using ABC, so that it would be possible to compare the coherence of results obtained by both methods. Since the analysis covers one year, the amounts of resources obtained were annualized in order to facilitate the evaluation process for the analyst.

After that, the scenario analysis was performed, according to the MIXBC method, using as reference the distribution of quantities inferred from ABC. In order to illustrate the mechanism of the analysis, Table 5 shows the analyses performed on the resource "budget analyst" of the engineering department.

It should be noticed that the amount of a certain resource to be used over a period of time can be evaluated in two different ways. For example, a business that has seasonal needs in its operations may require a particular professional only in the second semester. In this case, the necessary amount of the resource would be expressed as 1 worker $\times$ $6/12$ year, or 0.50 worker-annum. Let us consider another case in which the professional works part-time during the whole year. The necessary amount of this resource would be 50% of the working hours of a worker $\times$ 1 year $=$ 0.50 worker-annum. It should be noticed that relatively different evaluations may lead numerically to the same result. It is important that the cost analyst try to follow as far as possible the reality of the organization when he or she is making estimates. We would like to draw attention to the fact that an analysis may lead to different results, depending on the reality of each business and the viewpoint of the cost analyst.

Using the same guidelines, the scenarios for the other resources were analyzed and the necessary adjustments were made to meet the conditions of coherence posed by the method. The data shown in Table 6 were obtained.

The next step was to calculate the parameters of the MIXBC for each resource. Thus, the FPCs and FPDs (factors of cost participation and expenses of the mix, respectively) were obtained for each project (see Table 7).

TABLE 4 Simulation of distribution of resources in the Engineering Department, based on data provided by the example

ACTIVITIES	SIMULATED DISTRIBUTION OF RESOURCES											
	Budget analyst		Civil Engineer		Outsourced Project Designer		Architect		Draftsman		Building Technician	
	2,588.25 (R$ monthly)		11,050.00 (R$ monthly)		40,545.00 (budget)		7,650.00 (R$ monthly)		2,550.00 (R$ monthly)		4,479.50 (R$ monthly)	
Engineering Department	W-m[1]	R$	W-m	R$	Bg[2]	R$	W-m	R$	W-m	R$	W-m	R$
	36	93177	24	265200	1	40545	7	53550	24	61200	24	107508
Information Gathering	36	93177		0		0		0		0		0
Elaboration of projects		0	12	132600	1	40545	7	53550	24	61200	12	53754
Planning of works		0	12	132600		0		0		0	12	53754

[1]W-m: Months worked or worker-month.
[2]Bg: Budget.

TABLE 5 Analysis of scenarios in the MIXBC method for the resource "budget analyst" of the Engineering Department

EXCLUSIVE AND EXCLUDENT EQUIVALENT AMOUNTS PER ANNUM
(based on ABC)

ENGINEERING DEPARTMENT
Resource: Budget analyst
Unit: Worker-month

PAV.	SAN.	BUILD.	MIX	MIX-PAV	MIX-SAN	MIX-BUILD.
1.3	1.0	0.7	3.0	1.7	2.0	2.3

Scenario analyses:

- *In **exclusive production** scenarios for each project:*
  - *Only Paving works: ABC shows an average amount of 1.3 budget analysts necessary for a one-year period. This is equivalent to 1.0 budget analyst for a one-year period plus 1.0 budget analyst for a period of 0.3 year. A 1.0 budget analyst is deemed necessary for one year plus 1.0 budget analyst working part time (low use of resource), that is, 1.0 x 1.0 + 1.0 x 0.5 = 1.5 Worker annum.*
  - *Only Sanitation works: ABC shows that sanitation works consume on average 1 budget analyst for one year. This is the figure that will be used.*
  - *Only Building Construction works. ABC shows that building construction works consume on average 0.7 budget analyst for one year. This is equivalent to 1.0 budget analyst plus 0.7 per annum (average use of resource). The figure to be used is 1.0 Worker-annum.*
- *In **excludent production** scenarios for each project:*
  - *Absence of Paving works: In case no paving works are undertaken, ABC signals the need of 1.7 budget analysts for a year, or 1.0 x 1.0 per annum + 1.0 x 0.7 per annum (average use of resource). The figure to be used is 2.0 Worker-annum.*
  - *Absence of Sanitation Works: In case no sanitation works are undertaken, ABC signals the need of 2 budget analysts for a year. This amount will be used to make up the team.*
  - *Absence of Building Construction Works: In case no building construction works are undertaken, ABC signals the need of 2.3 budget analysts for a year, or 2.0 x 1.0 per annum + 1.0 x 0.3 per annum. In this case, there is a seasonal need for this resource at the end of the year (months of October, November and December). It is necessary to hire temporarily more 1.0 budget analyst.*

- *New distribution of amounts for resource "Budget analyst"(note that the amount of the MIX is not altered, since it is related to a real situation, with no scenarios):*

PAV.	*SAN.*	*BUILD.*	*MIX*	*MIX-PAV*	*MIX-SAN*	*MIX-BUILD*
1,5	*1,0*	*1,0*	*3,0*	*2,0*	*2,0*	*2,25*

- *It should also be noticed that the amount of resources available should not be exceeded in any situation (any amount ≤ MIX amount).*

Finally, the indirect costs and expenses corresponding to each project per resource, and, consequently per department, were calculated. It should be noticed that in the case of expenses, there was no longer the need for any kind of apportionment criteria; on the

TABLE 6 Results of scenario analyses for the resources of the Engineering Department

RESOURCES	EXCLUSIVE AND EXCLUDENT EQUIVALENT AMOUNTS PER ANNUM (analyzed)						
Engineering Department	PAV.	SAN.	BUILD.	MIX	MIX-PAV	MIX-SAN	MIX-BUILD
Budget analyst	1.50	1.00	1.00	3.00	2.00	2.00	2.25
Civil engineer	1.00	0.50	1.00	2.00	1.50	1.50	1.50
Outsourced project designer	0.20	0.40	0.65	1.00	0.90	0.75	0.50
Architect	0.17	0.17	0.50	0.58	0.58	0.58	0.58
Draftsman	0.50	1.00	1.50	2.00	2.00	1.50	1.00
Building technician	1.00	0.50	1.00	2.00	1.50	1.50	1.50

contrary, the analysis followed the same logic used for indirect costs using scenarios of absence in the MIXBC (see Table 8).

Evaluation of Results

Table 9 shows a comparison of the final results for indirect cost distribution carried out by ABC and MIXBC methods. It should be pointed out that the average result variation obtained by MIXBC in relation to ABC was only 2.06%, with a maximum deviation of 11.55% (13.61% - 2.06%) found in Paving works. The comparison shows that the results of both methods were relatively close.

The comparison of the final results of the distribution of expenses using the ABC and the MIXBC methods, as shown in Table 10, shows quite different results. This lack of closeness of agreement between results was expected, since the apportionment of the example taken from Rocha et al. (1999) had been carried out arbitrarily. The MIXBC results, however, show that the results of apportionment per number of hours are more coherent than those per revenue. In apportionment per hour, results show an average variation of 20.63% with a deviation of 58.54 points in Sanitation projects, whereas apportionment results per revenue display an average variation of 39.93% with a deviation of 105.58 points in Buildings projects.

The Income Statement displayed in Table 11 was prepared to compare the profitability of projects using the methods under analysis. Attention should be drawn to the fact that the positioning of projects in the profitability ranking did not vary, yet there were variations in the parameter "margin %," caused mainly by the differences in the distribution of costs and expenses that had been arbitrarily apportioned. In organizations where expenses are preponderant in the total production cost, MIXBC can offer surprising results, revealing incoherences hidden until then.

Conclusions

The MIXBC (mix-based costing) method was tested by comparing a situation in which ABC (activity-based costing) had already been applied, more specifically in the costing of civil construction projects.

TABLE 7 Parameters of the MIXBC method calculated from the results obtained by scenario evaluations

RESOURCES	MIXBC PARAMETERS (obtained from the analysis)									
	PAVING			SANITATION			BUILDINGS			
Engineering Department	CFmin	DCF	FPC	CFmin	DCF	FPC	CFmin	DCF	FPC	CF comp
Budget analyst	1.00	0.50	0.67	1.00	0.00	0.00	0.75	0.25	0.33	0.25
Civil engineer	0.50	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.50	0.50
Outsourced project designer	0.10	0.10	0.25	0.25	0.15	0.38	0.50	0.15	0.38	0.15
Architect	0.00	0.17	0.20	0.00	0.17	0.20	0.00	0.50	0.60	0.58
Draftsman	0.00	0.50	0.33	0.50	0.50	0.33	1.00	0.50	0.33	0.50
Building technician	0.50	0.50	0.50	0.50	0.00	0.00	0.50	0.50	0.50	0.50

TABLE 8 Distribution of indirect costs and expenses obtained using the MIXBC method

RESOURCES	COSTS AND EXPENSES SEPARATED BY MIXBC			
Engineering Department	CFpav	CFsan	CFbuild	CFtotal
Budget analyst	36,235.50	31,059.00	25,882.50	93,177.00
Civil engineer	99,450.00	66,300.00	99,450.00	265,200.00
Outsourced project designer	5,574.94	12,416.91	22,553.16	40,545.00
Architect	10,837.50	10,837.50	31,875.00	53,550.00
Draftsman	5,100.00	20,400.00	35,700.00	61,200.00
Building technician	40,315.50	26,877.00	40,315.50	107,508.00
	197,513.44	**167,890.41**	**255,776.16**	**621,180.00**
Supplies Department				
Storekeeper	7,857.78	14,204.44	24,177.78	46,240.00
Purchaser	8,899.30	8,899.30	21,221.40	39,020.00
	16,757.08	**23,103.74**	**45,399.18**	**85,260.00**
Human Resources Department				
Office assistant	3,400.00	13,600.00	13,600.00	30,600.00
Human resources assistant	56,000.00	156,800.00	89,600.00	302,400.00
Human resources manager	17,235.00	34,470.00	17,235.00	68,940.00
	76,635.00	**204,870.00**	**120,435.00**	**401,940.00**
Accounting Department				
Outsourced accounting services	7,308.00	20,097.00	9,135.00	36,540.00
	7,308.00	**20,097.00**	**9,135.00**	**36,540.00**
Financial Department				
Administrative assistant	9,180.00	9,180.00	18,360.00	36,720.00
Financial assistant	12,120.00	12,120.00	12,120.00	36,360.00
	21,300.00	**21,300.00**	**30,480.00**	**73,080.00**
Expenses	**DFpav**	**DFsan**	**DFbuild**	**DFtotal**
Compensation for services rendered	80,000.00	80,000.00	80,000.00	240,000.00
Managers	122,400.00	122,400.00	122,400.00	367,200.00
Maintenance and office supplies	14,536.00	24,950.40	26,753.60	66,240.00
Computer support	5,676.92	6,646.15	5,676.92	18,000.00
Expenses related to use of facilities	27,041.94	45,652.00	48,506.06	121,200.00
Office maintenance services	17,340.00	26,010.00	26,010.00	69,360.00
	266,994.86	**305,658.55**	**309,346.59**	**882,000.00**

Analyzing ABC and MIXBC results, it can be noticed that there was a significant closeness of results in relation to indirect costs. This closeness reveals internal coherence of the MIXBC algorithm, since very similar output was obtained using input calculated using ABC.

In relation to the distribution of expenses, there was a large discrepancy in the results. This was expected, since the scenario analyses of MIXBC of the resources that make up the

TABLE 9 Comparison of the distribution of indirect costs obtained using the methods ABC and CBMIX

	% IN ABC			% IN CBMIX		
DEPARTMENTS	Pav.	San.	Build.	Pav.	San.	Build.
Engineering	27.66	27.67	44.67	31.80	27.03	41.18
Supplies	16.67	29.78	53.56	19.65	27.10	53.25
Human Resources	18.23	50.04	31.74	19.07	50.97	29.96
Accounting	26.40	28.48	45.12	20.00	55.00	25.00
Financial	16.79	32.54	50.66	29.15	29.15	41.71
Total indirect costs	**23.09**	**35.51**	**41.40**	**26.23**	**35.90**	**37.87**
VARIATION OF TOTAL INDIRECT COSTS OBTAINED USING MIXBC IN RELATION TO THOSE OBTAINED USING ABC				**+13.61%**	**+1.09%**	**−8.53%**

TABLE 10 Comparison of the distribution of expenses obtained using the ABC and CBMIX methods

	ABC			CBMIX		
	Pav.	San.	Build.	Pav.	San.	Build.
Apportionable costs and expenses per revenue	**57.14%**	**28.57%**	**14.29%**	**30.27%**	**34.66%**	**35.07%**
VARIATION IN EXPENSES OBTAINED USING MIXBC IN RELATION TO THOSE OBTAINED USING APPORTIONMENT PER REVENUE				−47.02%	+21.29%	+145.51%
Apportionable costs and expenses per hour	**18.60%**	**55.81%**	**25.58%**	**30.27%**	**34.66%**	**35.07%**
VARIATION OF EXPENSES OBTAINED USING MIXBC IN RELATION TO THOSE OBTAINED USING APPORTIONMENT PER HOUR				+62.71%	−37.91%	+37.10%

expenses were not based on ABC distribution parameters, but rather were obtained from arbitrary apportionment (per revenue and per hour).

As regards the arbitrary apportionments in the example, the comparison with the MIXBC showed that the criterion of apportionment per hour is far more coherent than per revenue, despite the fact that significant differences were still found.

The comparison between income statements revealed that the MIXBC showed that the product “building construction projects” causes losses in the business operations, contrary to that indicated by the results of the ABC.

It should be pointed out that MIXBC is a method strongly dependent on the experience and on the systemic vision of cost analysts, who should have an in-depth knowledge of the reality of the business operations. The good foresight of these professionals shall be responsible for building coherent scenarios of resource consumption, and the application

TABLE 11 Comparison between profitability of projects obtained using the ABC method (using apportionment of expenses per revenue and apportionment per hours worked) and the MIXBC method

INCOME STATEMENT USING ABC + APPORTIONMENT PER REVENUE	Paving	Sanitation	Buildings	Total
Revenue	20,000,000.00	10,000,000.00	5,000,000.00	35,000,000.00
(Direct costs)	17,600,000.00	8,600,000.00	4,250,000.00	30,450,000.00
(Costs/Indirect Expenses: ABC +) Apportionment per Revenue	785,232.13	684,550.86	630,217.01	2,100,000.00
Gross Profit	1,614,767.87	715,449.14	119,782.99	2,450,000.00
Margin %	**8.07%**	**7.15%**	**2.40%**	**7.00%**
Ranking	**1°**	**2°**	**3°**	
INCOME STATEMENT USING ABC + APPORTIONMENT PER HOURS WORKED	Paving	Sanitation	Buildings	Total
Revenue	20,000,000.00	10,000,000.00	5,000,000.00	35,000,000.00
(Direct costs)	17,600,000.00	8,600,000.00	4,250,000.00	30,450,000.00
(Costs/Indirect Expenses: ABC + Apportionment per hours worked	445,325.15	924,829.93	729,844.92	2,100,000.00
Gross Profit	1,954,674.85	475,170.07	20,155.08	2,450,000.00
Margin %	**9.77%**	**4.75%**	**0.40%**	**7.00%**
Ranking	**1°**	**2°**	**3°**	
MIXBC INCOME STATEMENT	Paving	Sanitation	Buildings	Total
Revenue	20,000,000.00	10,000,000.00	5,000,000.00	35,000,000.00
(Direct costs)	17,600,000.00	8,600,000.00	4,250,000.00	30,450,000.00
(Costs/Indirect Expenses: MIXBC)	586,508.37	742,919.70	770,571.93	2,100,000.00
Gross Profit	1,813,491.63	657,080.30	−20,571.93	2,450,000.00
Margin %	**9.07%**	**6.57%**	**−0.41%**	**7.00%**
Ranking	**1°**	**2°**	**3°**	

of the method shall lead to the safe completion of the cost distribution task and to results free of arbitrary apportionments. It is recommended that the scenario analyses be performed by a multidisciplinary team, comprising professionals from human resources, production, and administrative managerial level.

It was also observed that the level of bureaucracy of the MIXBC is inferior to that of the ABC. MIXBC is, therefore, a valuable tool for the distribution of costs to products. It reduces the arbitrariness caused by traditional apportionment, and contributes to more profitable production strategies.

References

Beuren, I. M., de Souza, M. A. B., & Raupp, F. M. (2003). A Study on Using Costing Systems in Brazilian Companies. In: VIII Congress of the International Cost Institute, Punta del Este, Uruguay. *Proceedings*. Punta del Este, Uruguay. Retrieved from http://eco.unne.edu.ar/contabilidad/costos/ VIIIcongreso /110.doc

Binato, A., & Estrada, R. J. S. (2002). Cost Management for Small Business Activities. In: National Meeting of Production Engineering. *Proceedings*. Curitiba, PR. Retrieved from http://www.abepro.org.br/biblioteca/ENEGEP2002_TR32_0244.pdf

Di Gregorio, L. T., & Soares, C. A. P. (2012). Use of the Mix-Based Costing—MIXBC to Determine Product Profitability, Level of Attractiveness and Synergy of the Production Mix. *International Journal of Management*, 3(2). Retrieved from http://www.iaeme.com/Journalissue.asp

Isatto, E. L. (2003). The Costing Process in the Improvement of Civil Construction Processes: A Study of its Implications Under a Dynamic Perspective. In: Brazilian Symposium on Management and Economics of Construction. *Proceedings*. São Carlos, SP. Retrieved from http://www.deciv.ufscar.br/sibragec/ trabalhos/artigos/033.pdf

Kim, Y.-W., & Ballard, G. (2001). Activity Based Costing and Its Application to Lean Construction. In: Annual Conference of the International Group for Lean Construction, 9, *Proceedings*. Singapore. Retrieved from http://kczx.gzhu.edu.cn/course_center/files_upload/template/6C473DC0-9248-4A50-A2B2-04741AAD2F02/COLUMN_16/file3/ACTIVITY-BASED%20COSTING%20AND%20ITS%20APPLICATIONTO%20LEAN%20CONSTRUCTION.pdf

Martins, E. (2010). *Cost Accounting*, 10th Ed. São Paulo, Brazil: Atlas.

Rocha, J. G. C., Dias, J. C. S., & Coppini, N. L. (1999). ABC-Activity Based Costing: An Application for Construction Companies. *Journal of Science & Technology of Methodist University of Piracicaba*, 7(14). Retrieved from http://www.unimep.br/phpg/editora/revistaspdf/rct14art04.pdf

Schmidt, P., & Zornita, S. (2001). Application of ABC System in a Process of Construction. In: VII Congress of the International Cost Institute, II Congress of the Spanish Association of Directive Accounting, Leon, Spain. *Proceedings*. Leon, Spain. Retrieved from http://www.intercostos.org/documentos /Trabajo028.pdf

Soares, C. A. P., & Chinelli, C. K. (1998). A Deficiency of Production Processes and Management Systems as Factors of Technological Delay in Civil Construction. *Engevista*, 2(3).

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