DEVELOPMENT OF COST MANAGEMENT FOR THE CEMENT INDUSTRY IN NORTHEAST BRAZIL: A CASE STUDY

DESENVOLVIMENTO DA GESTÃO DE CUSTOS PARA A INDÚSTRIA DE CIMENTO NO NORDESTE DO BRASIL: UM ESTUDO DE CASO

DESARROLLO DE LA GESTIÓN DE COSTOS PARA LA INDUSTRIA DEL CEMENTO EN EL NORESTE DE BRASIL: UN ESTUDIO DE CASO

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ABSTRACT

The production of cement requires a suitable cost management tool to monitor overall expenses, calculate inventories, and improve control of activities that represent the flow of cement production. The aim of this study was to present a case study on the application of Activity Based Costing (ABC) in a cement plant located in northeastern Brazil. The methodology consisted of three main stages: characterization of the cement factory, diagnosis of the scenario before the implementation of ABC, and analysis of its practical application. The results allowed for the identification of how ABC facilitates decision-making, as it is a cost management tool for cost analysis that regulates the arbitrary allocation of indirect costs, thus allowing for the identification of non-value-added activities. The organization was divided into cost centers and cost generators, improving expense control. A total of 220 accounts were created to represent the areas and resources involved in cement production, as well as 145 instances of tasks. A detailed analysis of energy consumption in grinding allowed for the estimation of accurate costs for each type of cement. Although the total cost did not change, ABC allowed for a more in-depth analysis, increasing understanding of the cost system and the competitiveness and profitability of the company. This study provided support for an integrated view of the functioning of a cement industry with the application of ABC. Despite cultural barriers and the complexity of the method, the creation of cost centers and the identification of activities and cost generators enable active supervision of expenses.

KEYWORDS

Activity Based Costing; cement; cost management; cement industry.

RESUMO

A produção de cimento exige uma ferramenta de gestão de custos adequada para monitorar os gastos globais, calcular os estoques e principalmente melhorar o controle das atividades que representam o fluxo de produção de cimento. Este trabalho teve como objetivo apresentar um estudo de caso sobre a aplicação do Custeio Baseado em Atividades (ABC) em uma fábrica de cimento localizada no Nordeste brasileiro. A metodologia consistiu em três etapas principais: caracterização da fábrica de cimento, diagnóstico do cenário antes da implantação do ABC e análise da aplicação prática.

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Os achados permitiram identificar como o custeio baseado em atividades facilita a tomada de decisão, uma vez que é uma ferramenta de gestão para análise de custos que regula a alocação arbitrária de custos indiretos, permitindo a identificação de atividades que não agregaram valor ao produto. A organização foi dividida em centros de custos e geradores de custos, melhorando o controle dos gastos. Foram criadas 220 contas para representar as áreas e recursos envolvidos na produção de cimento e 145 instâncias de tarefas. A análise detalhada do consumo de energia na moagem permitiu estimar os custos precisos de cada tipo de cimento. Apesar de o custo total não ter sofrido alterações, o ABC possibilitou uma análise mais aprofundada, aumentando a compreensão do sistema de custos e a competitividade e rentabilidade da empresa. Este trabalho forneceu suporte para uma visão integrada sobre o funcionamento de uma indústria cimenteira com a aplicação do ABC. Apesar das barreiras culturais e da complexidade do método, a criação de centros de custos e a identificação de atividades e geradores de custos permitem uma supervisão ativa dos gastos.

PALAVRAS-CHAVE
Custeio baseado em atividades; cimento; gestão de custos; indústria de cimento.

RESUMEN
La producción de cemento exige una herramienta de gestión de costos adecuada para monitorear los gastos globales, calcular los inventarios y, principalmente, mejorar el control de las actividades que representan el flujo de producción de cemento. Este trabajo tuvo como objetivo presentar un estudio de caso sobre la aplicación del Costeo Basado en Actividades (ABC) en una fábrica de cemento ubicada en el noreste de Brasil. La metodología consistió en tres etapas principales: caracterización de la fábrica de cemento, diagnóstico del escenario antes de la implementación del ABC y análisis de la aplicación práctica. Los hallazgos permitieron identificar cómo el costeo basado en actividades facilita la toma de decisiones, ya que es una herramienta de gestión para el análisis de costos que regula la asignación arbitraria de costos indirectos, permitiendo la identificación de actividades que no agregan valor al producto. La organización se dividió en centros de costos y generadores de costos, mejorando el control de los gastos. Se crearon 220 cuentas para representar las áreas y recursos involucrados en la producción de cemento y 145 instancias de tareas. El análisis detallado del consumo de energía en la molienda permitió estimar los costos precisos de cada tipo de cemento. Aunque el costo total no sufrió alteraciones, el ABC permitió un análisis más profundo, aumentando la comprensión del sistema de costos y la competitividad y rentabilidad de la empresa. Este trabajo proporcionó apoyo para una visión integrada del funcionamiento de una industria cementera con la aplicación del ABC. A pesar de las barreras culturales y la complejidad del método, la creación de centros de costos y la identificación de actividades y generadores de costos permiten una supervisión activa de los gastos.

PALABRAS CLAVE
Costeo basado en actividades; cemento; gestión de costos; industria del cemento.

1. INTRODUCTION

Modern businesses frequently experience an increase in fixed expenses, typically due to the implementation of corporate automation. This consequently leads to higher costs for maintenance, depreciation, and necessary supplies. Additionally, there is a noticeable growth in the proportion of fixed expenses in indirect areas such as administration, human resources, and marketing. As a result of these rising costs and fixed expenses, their allocation using generic division criteria may result in inaccuracies when determining the costs of products and services (MARTINS, 2001; SABINO *et al.*, 2019; KNABBEN Jr. *et al.*, 2019).

The inception of Portland cement has catalyzed a profound revolution in the domain of construction, owing to its inherent hydraulic nature (i.e. the ability to cure in the presence of both air and water), malleability, exceptional durability under stress, and utilization of easily accessible natural materials (NWANKWO *et al.*, 2020; ABDUL-WAHAB *et al.*, 2021). Moreover, the resourcefulness of engineers, architects, and designers, combined with the precision of contemporary calculation methodologies, advanced the progress of cement innovations and, subsequently, concrete (LIMA, 2011; KHAN; McNALLY, 2023).

As a developing nation, Brazil necessitates a substantial infrastructure initiative (ALEIXO *et al.*, 2019). Cement is utilized as the primary base for the creation of dwellings, medical facilities, educational institutions, ports, airports, roads, highways, and hydroelectric facilities. This attribute highlights the significance of exercising careful regulation during its manufacturing and incorporation within the construction sector (CARVALHO, 2016; SHANKS *et al.*, 2019).

Since cement is a commodity, competition primarily arises through pricing and the quality of the final product (SNIC, 2013). Therefore, the implementation of a tool that enables better control of expenses and promotes the optimization of cement manufacturing processes, resulting in waste reduction, is critical for the survival of a company in this industry (MADLOOL *et al.*, 2011). As stated by Khoury (1997), unlike companies in the trade and service sectors, those in the industrial sector are greatly motivated and interested in adopting Activity Based Costing (ABC) due to intense competition and a wide range of products. Nevertheless, Azevedo *et al.* (2004) revealed that the utilization of ABC is limited in Brazilian companies, primarily due to the considerable investments required for data collection, the complexity of the cost allocation tool, and the need for personnel training.

According to Khoury (1997), most companies employ the Traditional Cost System (TCS), which generates auditable reports and adheres to Brazilian laws. Nonetheless, this method of cost calculation results in imprecise measurements for strategic decision-making due to the arbitrary distribution of indirect expenses.

The progress of information technology plays a significant role in the adoption of ABC in organizations (BJØRNENAK; MITCHELL, 2022). This is because ABC's fundamental principle is that activities consume resources and products consume activities, resulting in costs and expenses being initially categorized by activity. Furthermore, the concept of activity is more complex than that of a cost center or sector in an organization (ERASLAN; İÇ, 2020). Hence, from an operational perspective, the implementation of the ABC tool would be extremely challenging without the advancement of information technology (MARTINS, 2001).

Cokins (1996) stated that by closely monitoring activities and developing a deeper understanding of them, employees can come to recognize the significance of the cost driver - the primary factor that influences changes in costs. Put simply, this suggests that the increase in cost of one activity is directly correlated to the effort required by another supplier activity in meeting the demands of the customer activity.

Sabouri (2014) conducted a study on the viability of utilizing the ABC method in the cement industry. The study showed that the method was effective in reducing costs and implementing quality control systems. Sarwat and Godil (2017) examined the implementation of ABC in Pakistan's cement sector, emphasizing the impact of organizational variables and stressing the importance of managerial support and attitude in the adoption of this strategy. Nonetheless, their findings indicated that the size and structure of an organization did not have a significant correlation with the adoption of ABC. The authors suggested further investigation into the costs associated with implementation, level of support from management, satisfaction with the current costing system, and time expended.

In a study conducted by Robinson and Umo (2023), it was determined that there is a notable positive correlation between the ABC method and return on equity (ROE) among cement companies in Nigeria. The researchers suggested utilizing ABC due to its capacity to enhance profitability, highlighting it as a superior approach in comparison to alternative cost management strategies such as target costing, life cycle costing, and throughput accounting.

Oliveira *et al.* (2015) demonstrated the practicability of using the ABC method within the concrete production industry. They observed that the calculated cost showed a significant reduction of up to 75.6% when compared to the traditional approach. The researchers highly recommend the implementation of ABC due to its capacity to more accurately evaluate the profitability of products and enable the precise allocation of resources to more strategic and lucrative products. This, in turn, can enhance the effectiveness and efficiency of cost management.

Furthermore, research has linked the utilization of ABC to the sustainable growth of companies, specifically in the cement industry which is notorious for its significant carbon emissions (ROCHA *et al.*, 2022). Mashkoor *et al.* (2023) conducted a study examining the effects of ABC on sustainable development, demonstrating its ability to integrate environmental management with economic factors. Similarly, Yang and Chang (2018) discussed the application of ABC in the green sector, specifically in the recycling of blast furnace slag as a substitute for construction materials and cement. By implementing ABC, efficiency of operations improved, indirect costs decreased, and the company's competitiveness and profitability increased. Additionally, Akgün *et al.* (2023) assert that ABC can aid in reducing the environmental impact of industries associated with cement production.

In this respect, the objective of this research was to demonstrate a concrete example of implementing ABC in cement manufacturing, with the intention of improving the management of production costs. Nevertheless, prior to enacting ABC, it is essential to understand its theoretical principles.

2. ACTIVITY BASED COSTING

As indicated by Martins (2001) and Bertó and Beulke (2005), along with providing a comprehensive analysis of product costing, ABC also offers improved opportunities for identifying areas of inefficiency and serves as a means of cost management. Its purpose is to minimize the arbitrary allocation of indirect costs.

The expenditures categorized as indirect costs are not as readily apportioned to individual products, whereas direct costs can be directly assigned to the products (PINTO *et al.*, 2008). Figure 1 illustrates the steps of the methodology employed to conceptualize ABC and present the case study, with activities further subdivided.

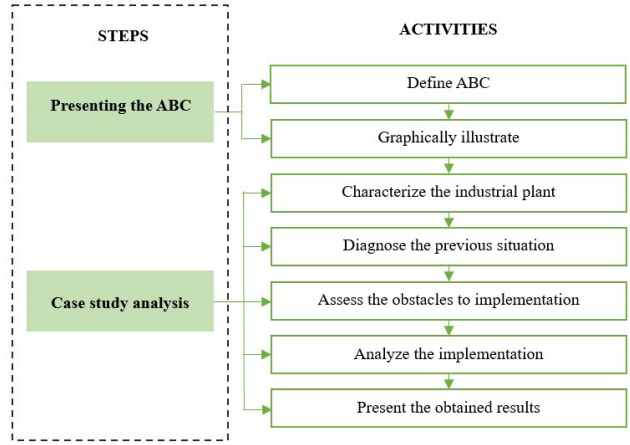

Figure 01: Flowchart outlining the methodology steps for developing the project
Source: Elaborated by the authors.

ABC is divided into resources, activities, and objects. Resources are the expenditures in their immature state, denoting the amounts disbursed that are readily observable. Instances of resources encompass electricity, wages, and inputs. Activities signify the outlay of resources essential to carry them out, while objects denote the commodities created by the company (MARTINS, 2001).

The cost drivers encompass the elements that ascertain the root cause of the cost (MARTINS, 2001). They illustrate how the activities will deplete the resources and how the objects will use the activities. Instances of drivers comprise the employee count, quantity of items ordered, amount of kWh consumed, and number of work hours.

The flowchart shown in Figure 2 displays the operation of the hierarchy of resources, actions, objects, and factors. Each resource, action, or object incurs or assigns its expenditures in a consecutive manner. To illustrate, the initial emphasis was on labor. The costs of each department or equipment (Human Resources - HR, General Maintenance, and Cement Mill) will be utilized by their corresponding activities. This constitutes the second emphasis. The third focus was on the principal service provider, specifically the HR activity. In exchange, the General Maintenance activity serves the cement grinding activity, which also necessitates electricity for its functioning (fourth focus). The fifth and ultimate emphasis was on the grinding of clinker and additions, specifically the production of cement. As each focus involved the transfer of costs, the total resources expended should be equal to the total cost of the objects.

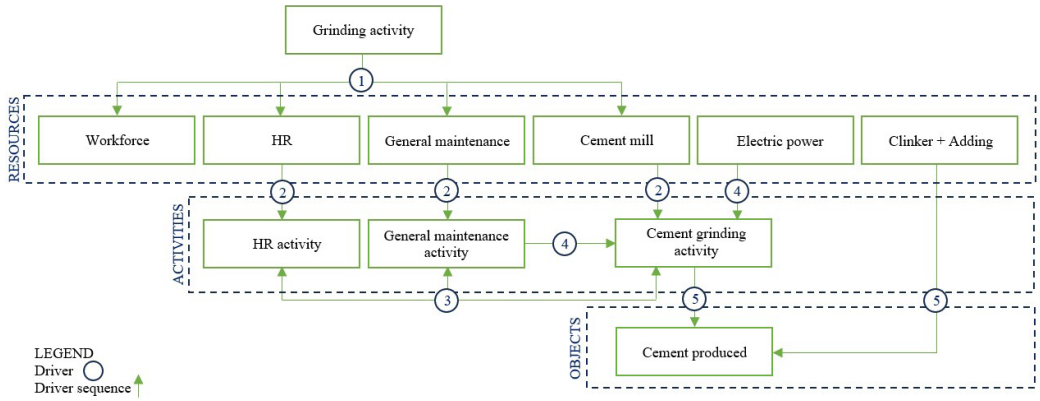

Figure 02: Flowchart outlining the methodology steps for developing the project

Source: Elaborated by the authors.

For example, in Figure 3, the human resources department distributes its expenses based on the number of employees in other departments. This is a logical approach, as in the studied cement plant, the workload of the HR department was directly proportional to the number of employees in various areas of the company. This includes tasks such as managing vacation requests, calculating labor taxes, and evaluating overtime and shift work. In numerical terms, if the HR department's expenses were US$10,000 and the total number of employees in other departments was 35 (20 in General Maintenance, 10 in Cement I Grinding, and 5 in Cement II Grinding), this would result in a contribution of US$5,714.29 for General Maintenance (20/35 x US$10,000), US$2,857.14 for Cement I Grinding (10/35 x US$10,000), and US$1,428.57 for Cement II Grinding (5/35 x US$10,000).

The maintenance process as a whole utilizes the number of hours that the drivers work on each piece of equipment. This indicates that each operation necessitates a suitable driver, depending on its specific role within the company.

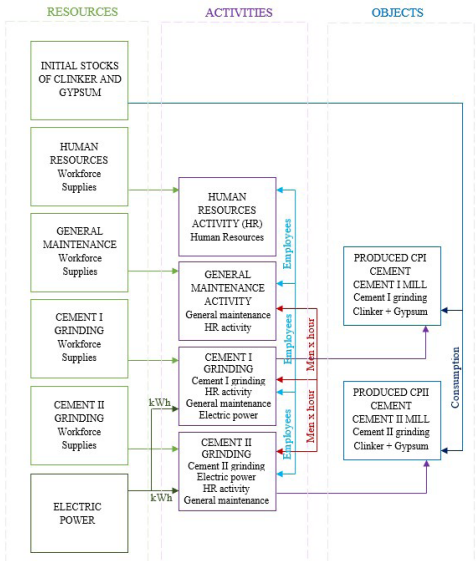

Figure 03: Flowchart of ABC

Source: Elaborated by the authors.

Every cost center, such as General Maintenance, Cement Mills, and HR, is designated as a resource in the cost chart template. As the distribution of resources and items is relatively simple, the primary difficulty for ABC is how to assign direct operations and, specifically, those that are indirectly connected to the production process.

Regarding the production activities, specifically Cement I and II Grinding, their targeting was based on intuition as each activity produced only one type of product. Therefore, the Cement I Grinding Activity directs 100% of its expenditures towards CP I cement, which is produced at the Cement I Mill. Similarly, Cement II Grinding is focused on producing CP II cement. It is important to note that when each of these production activities allocated their costs to the products, they also transferred a portion of their expenses that contributed to the overall cost. For example, when the Cement I Grinding activity allocated its full cost to CP I cement, it also included the costs of electricity, as well as the impact of HR and General Maintenance activities, as shown in Figure 4.

Figure 04: Flowchart of ABC

Source: Elaborated by the authors.

Another important factor to consider is that the motivation for performing maintenance activities is the number of hours dedicated by workers. In simpler terms, it is the result of the total hours worked by the employees assigned to a particular task. This driving force, much like the human resources aspect, is highly rational.

Each activity possesses an optimal driver, which is ascertained by its function within the company and the extent of demand from other departments.

3. METHODOLOGY

The methodology consisted of three stages: first, the characterization of the industrial plant to identify the unique aspects of the factory's production capacity; second, the diagnosis of the previous situation regarding cost management; and finally, the analysis of the practical implementation of ABC, assessing the obstacles that naturally arise when restructuring the organizational process and implementing management tools such as ABC.

According to Martins (2001) and Bertó and Beulke (2005), in addition to offering a comprehensive overview of product costing, providing improved means of identifying inefficiencies, and functioning as a means of cost management, ABC strives to minimize the arbitrary allocation of indirect expenses.

3.1 Characterization of the industrial plant

This paper discusses a case study of a cement industry with a daily clinker production capacity of 2,000 tons and an hourly cement production capacity of 140 tons. The plant, including its mining and cement sales areas, employed a total of 570 individuals.

The main energy-consuming process in the plant was the grinding of cement in two mills, which accounted for approximately 35% of the overall energy usage. Notably, these mills were not identical; one had a much higher production capacity and productivity. Despite this difference, both mills were responsible for producing the two types of cement sold by the company: CP II-Z 32 and CP II-F 32.

3.2 Assessment of the previous state of cost management

There existed a cost accounting system that operated through cost absorption. As stated by Moura (2005), this approach, in addition to adhering to tax regulations, places particular emphasis on the allocation of production expenditures overall, frequently employing capricious allotments for the assessment of inventory.

Only production-associated costs were apportioned to the cost of goods sold. Overhead expenditures, including those related to personnel, administration, and marketing, were not eligible for inclusion in the cost of goods sold for the purpose of income taxation.

In conclusion, the cost situation was strongly influenced by the tax regulations. The initial concept regarding the performance of a specific equipment became unclear within the previous framework for cost calculation. Table 1 demonstrates the presentation of the cost data. The underlying factors contributing to resource usage for each machine were not considered. Therefore, the cost of the produced cement was determined as an average of the two types. The expenses for each account were combined and ultimately divided by the total cement production.

Cost contributions	Values in US$	%
Clinker	2,307,420.0	78.4
Electric power	208,251.0	7.1
Replacement materials	127,264.0	4.3
Crushed natural pozzolan	109,826.0	3.7
Crushed gypsite	77,570.0	2.6
Indirect manufacturing expenses	32,237.0	1.1
Third-party services	30,852.0	1.0
Crushed limestone	27,577.0	0.9
Direct workforce	30,268.0	0.7
Total (US$)	2,941,266.0	
Production (tons)	65,000.0	
US$/tons	45.25	
Administrative expenses	54,889.0	
Total expenses	2,996,155.0	

Table 1: Cost contributions of cement produced in one month
Source: Elaborated by the authors.

3.3 Analysis of the practical implementation of ABC

Despite the perpetual necessity to strive for constant process enhancement, many organizations frequently face well-established obstacles when attempting to implement systems and methodologies that alter their current routines.

Several barriers, primarily of a cultural nature, were identified during the adoption of ABC. Some individuals perceived the new cost methodology, which required comprehensive data on organizational activities, as a form of surveillance rather than a tool for enhancing work management.

These hindrances have been taken apart and are consistently being overcome through earning the trust of individuals. It is essential to explicitly state that without

the support of the general population, it would not be feasible to provide reliable information and assistance for decision-making by management.

In addition, the exchange of feedback is vital for earning the dedication of users and ensuring the effectiveness of cost management. As stated by Cunha *et al.* (2005), the practice of giving and receiving feedback utilizes interpersonal relationships as a means of advancing the overall growth of the organization.

The implementation of ABC necessitates reconfiguring business processes to an appropriate level of specificity in order to avoid excessive length or brevity. All processes within the organization fundamentally involve utilizing resources, producing a product or service, and engaging customers (COKINS, 1996).

After initial meetings with department managers, the entire organization was mapped and divided into cost centers. These meetings also aimed to understand the tasks performed by each sector and illustrate their interdependence. As shown in Figure 5, the Human Resources department's main responsibilities were closely connected to the number of employees in other departments. In contrast, the workload of the Materials Management department was directly influenced by the demands of other sectors in the company.

It should be noted that an internal team was established to oversee cost management and enhance comprehension of the new costing methodology. Without the formation of this team, successful implementation may not have been feasible. As expressed by Senge (2002), team learning serves as a paradigm for learning within the organization, as the team's accomplishments can establish a precedent and standard for collective learning throughout the entire organization.

Figure 6 illustrates the flowchart outlining the stages of ABC implementation at the cement plant. Each phase depicted in Figure 6 has been assigned a numerical designation to facilitate understanding of the descriptions provided in Table 2.

After holding meetings with the managers of different departments in the company, the organization was partitioned into cost centers. This enabled the direct allocation of costs, including cash expenditures, material requisitions, personnel allocation, and third-party services. The number of cost centers established was based on the level of specificity required to efficiently monitor the specific expenses of each activity or process.

Once the cost centers were set up, it became imperative to develop cost drivers. These were responsible for determining the utilization of each resource, activity, or object.

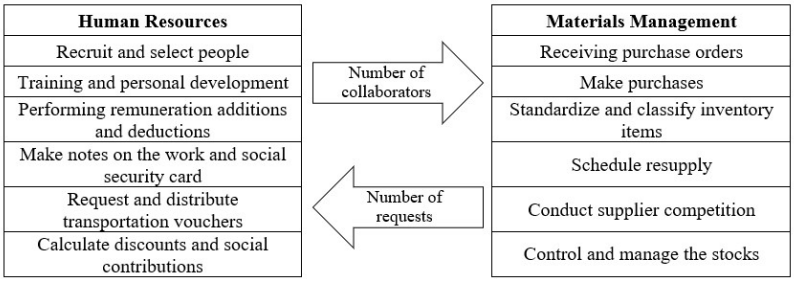

Figure 5: Interdependence among the various sectors of the company

Source: Elaborated by the authors.

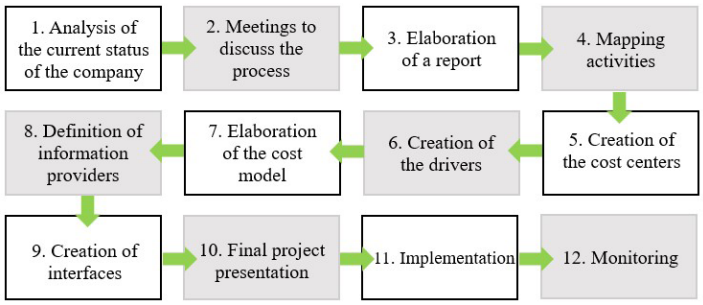

Figure 6: Flowchart outlining the implementation stages of ABC

Source: Elaborated by the authors.

#	Implementation Phases	Activity description
1	Analysis of the status of the company	Study the accounting reports, analyze the production bulletins, and check how the production controls are performed.
2	Meetings to discuss the process	Hold meetings with the managers of each area to discuss the processes performed by each sector, be it the production, production support, administrative, or commercial areas.
3	Elaboration of a report	Prepare a report with the diagnosis of the company and with the descriptions of the processes practiced by the areas or sectors of the company. In addition, it is important to inform the results expected with the implementation of ABC.
4	Mapping activities	List all the activities that will be costed.
5	Creation of the cost centers	Create a table with the cost centers that will be used to allocate the expenses of each sector of the company.
6	Creation of the drivers	Create a table with the drivers that will be used to identify how resources, activities and objects will be consumed
7	Elaboration of the cost model	Create the cost model in a specific program responsible for doing the cost calculation.
8	Definition of information providers	Define with the area managers those responsible for delivering the necessary data to feed the cost model.
9	Creation of interfaces	Define with the IT area the format of the data that will be delivered by the information providers, to feed the cost model.
10	Final project presentation	Present to the managers, manager, and director the result of the project, with the cost simulation with a monthly period and making the comparison with the previous situation of the company with reference to cost management.
11	Implementation	Set a date to start the monthly cost calculation. Define with the information providers the deadlines for sending data to feed the cost model.
12	Monitoring	Follow up on the monthly cost calculations.

Table 2: Description of the implementation stages of ABC
Source: Elaborated by the authors.

The cost of relocating inputs within the factory and transporting materials from the mine to the plant by means of trucks incurred expenses that were unable to be allocated to the improvement of product quality. In contrast, the higher the expenses for transportation and handling, the lower the profit, as these costs could not be passed on to the final price of the products without the risk of losing market share.

According to Kaplan (2010), it is possible to include the element of time in ABC in order to optimize the utilization of resources, such as personnel, machinery, technology, and physical space, and comply with the operating expense budget.

Hence, the expense incurred for the operations performed by the machinery responsible for the transportation of raw materials was computed based on their efficient utilization per unit of time. As an example, the budgeting for the process of extracting limestone, which relied on crawler tractors and excavators, was determined by the hourly unit cost of each equipment's availability. The allocated time for each equipment corresponded to the workload of the operators engaged in the limestone extraction task, not including maintenance hours.

4. RESULTS

The initial result was the division of the entire organization into cost centers and cost drivers, thereby increasing the ability to control expenses in each department of the company. Oliveira *et al.* (2015) also noted that the ABC method is suitable for companies in the concrete sector, as it

enables a more precise calculation of the impact of each department and employee on the final cost of the product. This contributes to a more well-directed allocation of organizational resources, enhancing efficiency and effectiveness in cost management. For example, Figure 7 illustrates the contributions of activities and resources in the flour grinding process, which is responsible for producing the flour used in the clinker kiln.

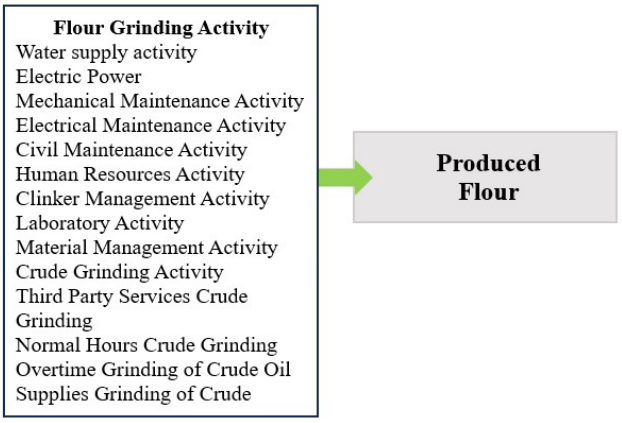

Figure 7: Contributions of the flour grinding activity
Source: Elaborated by the authors.

Each step in the process of grinding flour assigned its costs based on a designated driver. For instance, the laboratory step distributed its expenses according to the quantity of tests and laboratory analyses performed during the monthly period.

In order to obtain a thorough comprehension, 220 accounts were created to represent the areas and resources involved in the production of cement. In terms of tasks, 145 instances were produced, covering production, support for production, administrative, and commercial functions.

As a cost flow analysis tool, ABC not only delineated the company's operations but also allowed for the categorization of these activities based on their value aggregation using the criteria outlined in Figure 8. This instilled a culture focused on minimizing process losses, optimizing maintenance activities, and reducing unnecessary expenses associated with input movement. According to Yang and Chang (2018), the implementation of ABC enhanced the efficiency of activities and decreased indirect costs, ultimately bolstering the competitiveness and profitability of the company. Additionally, it facilitated the identification of distorted cost discrepancies and cross-subsidization among individual products, thereby improving production and marketing strategies and maximizing profitability.

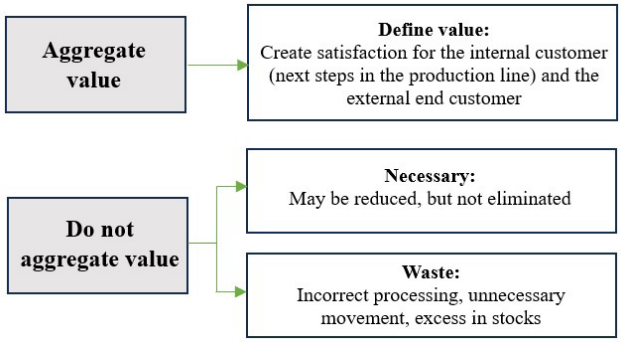

Figure 8: Criteria for aggregating value to the activities
Source: Elaborated by the authors.

Only the activities that resulted in the transformation of the product (LIKER, 2005) were classified as value-adding activities, as it is this transformation that generates the perception of value for both internal and external customers in the field of cement manufacturing. Table 3 outlines some of the key activities that contribute and do not contribute to the value of the cement manufacturing process.

Activities that aggregate value	Activities that do not aggregate value
Limestone Extraction	Limestone stripping
Crushing	Fuel storage
Pre-homogenization	Fuel handling
Flour Grinding	Supply Handling
Clinkerization	Furnace heating
Cement Grinding	Maintenance
Bagging	Water supply

Table 3: Main activities that add and do not add value
Source: Elaborated by the authors.

The expenses incurred for the handling of inputs in the mill and mine were calculated. However, these costs were not allocated towards enhancing the product's features. Therefore, the handling activities did not add value to the product (LIKER, 2005). In this regard, Oliveira *et al.* (2015) also noted that the implementation of the ABC method allows for a better evaluation of the profitability of each product and informed decisions on the continuity or elimination of production lines. The ABC method enables the precise allocation of resources to the most profitable or strategic products.

It should be noted that the clinkerization process involves the consumption of fuel to produce thermal energy. However, this fuel is not incorporated into the final product as it is dissipated during the process. Therefore, it is considered a non-value-adding element.

Following the implementation of the ABC system, the integration between different areas of the plant

significantly improved, as each area recognized its impact on the final product's cost. According to Kaplan (2009), the frequency of operational analysis meetings should be determined based on the company's operational cycle and the speed at which managers want to respond to sales and operational data. As a result, these meetings became more frequent, allowing for discussions on preventive and corrective maintenance, production schedules, inventory levels, defects, and equipment downtime.

Figure 9 depicts the costs of cement production for each mill. This segregation of product costs enabled the computation of the individual product contribution margin, thus identifying the one that would yield the highest financial and economic gain for the company.

The cement grinding process was conducted with consideration for the energy consumption needed to produce each type of cement in each mill. This method resulted in a more precise estimation of the cost for each cement, as the maintenance tasks and replacement of plates and grinding bodies in the mills were a result of wear and tear caused by the reduction of material within the equipment. This reduction was solely achieved through the use of electricity, which is the main contributor to the cost of cement grinding. Furthermore, Sahoo and Kumar (2022) also point out that cement production requires a significant amount of energy and is responsible for greenhouse gas emissions. Therefore, it is imperative to enhance energy efficiency and reduce emissions, primarily in the grinding activities.

It is crucial to keep in mind that, regardless of the methodology used to calculate expenses, the total cost of US$ 2,996,155 remained unchanged. However, in the ABC methodology, the result was significantly more comprehensive and meticulous, as each activity began to impact the cost flow based on its actual usage. Therefore, the outcomes are related to greater benefits in terms of a better understanding of the actual cost system by identifying the main activities, demonstrating that the ABC method can be applied in the cement industry, as recommended by Robinson and Umo (2023) in Nigeria and Sarwat and Godil (2017) in Pakistan.

Table 4 illustrates that CP II-F cement, regardless of its production source, consumed a significantly higher level of electricity per metric ton of cement manufactured. This can be attributed to its higher clinker composition, which possesses a greater degree of grinding difficulty (ABCP, 2002). Therefore, this led to a higher cost of grinding for this cement in comparison to CP II-Z.

ACTIVITIES

Cement 1 Grinding Activity	**US$ 292,994**	**50,000.00 t**	**US$ 5.86/t**
Cement 1 Grinding Activity	US$ 111,774		US$ 2.23/t
HR Activity	US$ 1,005		US$ 0.02/t
Materials Activity	US$ 1,432		US$ 0.03/t
Electrical Maintenance Activity	US$ 7,307		US$ 0.15/t
Mechanical Maintenance Activity	US$ 6,589		US$ 0.13/t
Civil Maintenance Activity	US$ 3,601		US$ 0.07/t
Electric Power	US$ 161,317		US$ 3.23/t

Cement 2 Grinding Activity	**US$ 133,520**	**15,000.00 t**	**US$ 8.90/t**
Cement 2 Grinding Activity	US$ 66,640		US$ 4.44/t
HR Activity	US$ 1,005		US$ 0.07/t
Materials Activity	US$ 430		US$ 0.03/t
Electrical Maintenance Activity	US$ 6,189		US$ 0.41/t
Mechanical Maintenance Activity	US$ 8,721		US$ 0.58/t
Civil Maintenance Activity	US$ 3,601		US$ 0.24/t
Electric Power	US$ 46,934		US$ 3.13/t

ENERGY CONSUMPTION (kWh/t x produced tons)

OBJECTS

CP II-F MC1 Cement	**US$ 558,417**	**12,000.00 t**	**US$ 46.53/t**
Cement 1 Grinding activity	US$ 70,467		US$ 5.87/t
Supplies	US$ 487,950		US$ 40.66/t

CP II-Z MC1 Cement	**US$ 1,790,290**	**40,000.00 t**	**US$ 44.76/t**
Cement 1 Grinding activity	US$ 222,527		US$ 5.56/t
Supplies	US$ 1,567,762		US$ 39.19/t

CP II-F MC2 Cement	**US$ 153,739**	**3,000.00 t**	**US$ 51.25/t**
Cement 2 Grinding activity	US$ 31,752		US$ 10.58/t
Supplies	US$ 121,987		US$ 40.66/t

CP II-Z MC2 Cement	**US$ 493,709**	**10,000.00 t**	**US$ 46.53/t**
Cement 2 Grinding activity	US$ 101,768		US$ 10.18/t
Supplies	US$ 391,941		US$ 39.19/t
Total	US$ 2,996,155		

Figure 9: Cost contributions of the cement produced in one month

Source: Elaborated by the authors.

Cement 1 Mill	Specific consumption	Production	Power consumption
CP II-F Cement	44.0838 kWh/t	12,000.00 t	529,005.70 kWh
CP II-Z Cement	41.7636 kWh/t	40,000.00	1,670,544.30 kWh
		Total	2,199,550.00 kWh
Cement 2 Mill	**Specific consumption**	**Production**	**Power consumption**
CP II-F Cement	50.7277 kWh/t	3,000.00 t	152,183.23 kWh
CP II-Z Cement	48.7767 kWh/t	10,000.00 t	487,766.77 kWh
		Total	639,950.00 kWh

Table 04: Targeting the cement grinding activity (specific energy consumption (kWh/t) x cement produced tons)

Source: Elaborated by the authors

5. CONCLUSIONS

The implementation of Activity Based Costing (ABC) in a cement plant allowed for the categorization of costs related to the core operations of the company, as well as those associated with intermediate and final products. Additionally, it facilitated the identification and classification of all auxiliary and inherent activities involved in the production of flour, clinker, and cement, based on their value contribution. Therefore, aside from determining the costs of the end products, ABC serves as a valuable management tool when paired with a thorough understanding of the company's production process.

The primary obstacle faced in implementing ABC in the company examined was the cultural barrier among most employees, resulting from the intricacy and complexity of the costing method. However, with the establishment of designated cost centers and the identification of activities and cost drivers, various departments within the company were able to closely and actively monitor their expenses, resulting in an overall reduction in costs for the cement company.

This study may prompt managers of companies, regardless of their industry, to consider the possibility of implementing ABC as a means of optimizing and overseeing expenses and operations.

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GFHB: conceptualization, data duration, formal analysis, investigation, methodology, validation, writing - original draft and writing - review and editing.
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ACLJ: conceptualization, funding acquisition, investigation, methodology, project administration, supervision, visualization, writing - original draft and writing - review and editing.
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