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Logistics cost management in foundry production using the Activity – Based Costing method

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Abstract: The aim of the paper is to present the application of Activity-Based Costing (ABC) method in logistics cost management in foundry production and its practical use in differentiating logistics service levels. The study was carried out in a foundry specializing in custom and small batch production of castings. The implementation of the ABC method involved three key phases. Tools such as Pareto analysis and the Lorenz curve were used to analyse the customers, which enabled the classification of customers according to their contribution to profit. The main result of the research was the creation of a calculation formula allowing detailed allocation of logistics costs to individual activities. At the same time, the key benefits of the ABC method for logistics management of foundry production were identified. The method was also used to analyse customers, which led to differentiation of logistics service levels based on their economic benefits. The main benefit of the implementation of the ABC method was the accurate allocation of logistics costs to activities, which enabled a better understanding of the economic efficiency of logistics processes. However, the study was time and data intensive, with some of the data based on educated guesses, which may have affected the accuracy of the results. Moreover, the focus on custom foundry production limits the generalizability of the conclusions. However, the ABC method has opened up new opportunities for data automation and optimization of logistics processes through digital technology, which contributes to modernise logistics management in foundry production.

1 Introduction

In the current economic environment, defined by constant changes in customer preferences, the rapid pace of technological innovation, and growing competition, systematically strengthening the competitiveness of companies is a necessity. This aspect affects all business sectors, including foundry industry, which is classified as part of the metallurgical industry. It is a field with extraordinary capital intensity, requiring the allocation of a large amount of financial resources to technology, technical equipment and environmental protection of processes.

In an increasingly complex business environment, there is a growing demand to ensure the efficiency and speed of material and information flows associated with meeting product demand. These flows cover the entire cycle from demand generation to the final distribution of products, including their support and subsequent disposal [1]. Successful management of these logistics chains is essential to maintain the competitiveness of the company. With the increasing complexity of industrial supply chains and the growing division of labour, the share of logistics costs in total production costs is increasing significantly [2]. Accurate allocation of logistics costs, including the detailed identification of individual processes throughout the entire logistics chain, is becoming increasingly important. However, the high complexity of logistics operations and the limited information on indirect costs significantly complicate the allocation process [3]. Therefore, innovations in costing methods are becoming a prerequisite for the effective reduction of logistics costs [4].

The aim of the paper is to present the use of the Activity - Based Costing (ABC) method in managing logistics costs for foundry companies and its potential further applications for optimizing logistics processes.

2 Theoretical background

Logistics is defined in both academic and practical contexts through the physical flows and the associated information and financial flows, which are essential for meeting product demands. Typical logistics activities include demand forecasting, logistics chain design, sourcing, customer order processing, inventory management, production and service planning, material handling, packaging, warehousing, transportation, reverse logistics management, and post-sales support [5].

The objective of logistics is to achieve a high level of logistics service while meeting the requirements of end customers at an acceptable total cost for all parties involved. A process can be defined as a group of logically arranged activities during which input resources are transformed into output products, whether they are about products or services. By linking these processes, which are necessary for meeting customer product requirements, a logistics chain with a line structure is formed. A higher

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level of complexity is found in a logistics network, where flows are disconnected or connected, and some processes run in parallel [6].

The mission of logistics management is to organise and direct flows to achieve logistics objectives, at both the intra-company and inter-company levels. A systems approach and process orientation must be applied. By adhering the system approach, it is useful to distinguish three functional areas of logistics management, namely purchasing, production and distribution logistics [5,6]. Logistics management tools are often associated with lean manufacturing principles, as the primary goal of logistics is to enhance process efficiency [7].

Organising, managing and operating the logistics chain incurs logistics costs. Logistics costs can be classified according to the nature and purpose of the flow:

- the costs of organising and managing the flow,
- the costs of implementing the flow,
- holding costs,
- costs arising from an inadequate level of logistics services [5,6].

In today's economic environment, logistics costs are a key factor in determining competitiveness across all industries. However, the high complexity of logistics processes and the lack of accurate data on indirect costs makes their effective allocation to cost objects significantly more difficult [4].

Under the traditional costing method, costs are divided into direct (variable) and indirect (overhead) costs. A large part of the logistics costs consists of overheads, which are included in the overall overhead. If overheads are presented in an aggregate form as supply, production, sales and administrative overheads, it is not possible to determine exactly how individual processes and products utilize resources. For the purposes of efficient logistics management, however, it is essential to understand how costs are affected by, for example, packaging methods or the chosen means of transport. This raises the question of how to fairly allocate logistics overheads fairly to individual products and which costing method to choose for this purpose [6]. To some extent, modern methods such as Activity-Based Costing and Time Driven Activity-Based Costing (TD-ABC) offer some answers to this challenge [8].

The foundations of Activity-Based Costing can be tracked back to Professor Kohler, who first introduced the concepts of cost allocation in 1952. In 1988, this idea was further developed by Robin Cooper and Robert Kaplan and formulated the ABC method [9]. The essence of ABC costing lies in the allocation of indirect costs to individual activities, through which these costs are assigned to cost objects based on a causal relationship between the economic resource and the cost object [10]. From a methodological perspective, it involves a full cost calculation (the absorption method), which can be combined with the non-absorption method. The implementation of the ABC method is divided into three key phases. In the first phase, the reasons for implementation are defined, and the structure of the ABC model is established. In the next step, an analysis of the implementation costs is conducted, and the expected outputs of the system are defined. The second phase is model creation, which includes the implementation of the individual steps for developing the ABC system creation. In the third phase, the system is put into operation, and the area of automatic retrieval is simultaneously addressed along with data processing to ensure the system's complexity [11,12].

The shortcomings in the application of the ABC method became the impetus for developing the modified TD-ABC method [13]. The calculation allocates costs to activities based on time usage. The logic of the TD-ABC method differs from that of the ABC approach in that, while the ABC method requires repeated identification of the actual occurrences of controlling factors for each activity, the TD-ABC method only requires a single temporal equation that mathematically models all possible variations in the course of a given activity. It expresses the dependence of activity time consumption on time factors. The TD-ABC method appears suitable in situations with significant heterogeneity in both input and output resource consumption that cannot be captured by the traditional ABC model [11,13].

A review of the literature in this area reveals that there are several case studies and research focused on logistics cost management and the application of the ABC method in various contexts.

Research conducted by Aksoylu and Demirel [1] explored the use of ABC in reverse logistics, specifically focusing on the recovery of end-of-life vehicles (ELV). The research critiques traditional accounting methods for their inadequacy in allocating overhead costs and demonstrates how ABC offers improved insight into costs. The case study focuses on a dismantling facility where vehicles are treated as inputs and reclaimed materials as outputs. The authors conclude that ABC is a valuable tool for companies to manage their reverse logistics costs effectively, and the presented model can be applied to other sectors engaged in reverse logistics.

Kučera [2] examined the application of the ABC method for calculating logistics costs in the automotive warehousing industry. The study emphasizes how accurate costing supports better decision-making and increases profitability. Through a case study of a logistics service provider, it demonstrates that ABC provides a detailed view of the cost structure, leading to a better cost optimization and pricing strategy. Kučera concludes that ABC is a key tool for effective cost management and improved competitiveness in the automotive industry.

Zhang and Li [3] focused on the use of the ABC method in logistics cost management, emphasizing its importance for cost reduction in a globalized economy. The case study

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showed how the transition to ABC enhanced the accuracy of calculations and pricing strategies. The study also pointed out the delay in the application of ABC in the Chinese logistics sector. The authors conclude that ABC provides a more sophisticated approach to cost accounting compared to traditional methods. This is especially true for operations characterised by low performance, high indirect costs, and personalised services, which are typical features of logistics companies.

A study by Duran and Afonso [4] presents an Activity-Based Life Cycle Costing **(**AB-LCC) model for life cycle cost assessment in spare parts logistics. The model, which integrates the Weibull distribution to estimate demand and costs for non-repairable spare parts, offers more accurate costing and inventory optimisation than traditional methods. The case study shows that AB-LCC provides a more detailed view of costs and contributes to efficient inventory management. The authors recommend further research focused on technological change and risk simulation.

The authors Jin and Li [9] investigated how the competitiveness of third-party logistics (3PL) companies can be enhanced through cost optimisation. The authors combine the ABC method, programme analysis, and Flexsim simulation software to improve logistics operations at L Corporation. The study reveals that transport, warehousing, and distribution are the main cost areas and proposes optimisations that have led to a 12.5% cost reduction for selected customers. The results show that combining the ABC method with other tools effectively identifies and resolves operational problems, leading to increased efficiency and reduced costs in 3PLs.

3 Logistics cost management in foundry production using the ABC method

A case study was conducted to demonstrate the application of the ABC method in logistics cost management in foundry companies. The production programme of the foundry is focused on unit production and small-batch production of castings from steel (non-alloy, low-alloyed), cast iron with flake graphite (LLG), cast iron with spherical graphite (LKG) and non-ferrous metals (aluminium and copper alloys). Production commences only upon a specific customer order. The "customer order disconnection point" is situated in the material and raw material warehouses at the manufacturer's so-called Make-to-Order. The wide variability of materials used and the custom nature of production in the foundry lead to a high variety of cost structures that traditional costing methods cannot adequately capture. For this reason, the introduction of a modern ABC costing approach was proposed.

In the first phase, the reasons for implementation were identified, and the structure of the ABC model was established. The strategic variant of the model was chosen, characterised by fewer activities to which costs are allocated over a longer time period. Subsequently, the implementation costs were analysed and the expected outputs of the system were defined. The second phase included the actual creation of the model, with the implementation of the individual steps necessary for the implementation of the ABC system. In the third phase, the system was put into operation, ensuring automated data acquisition and processing to achieve full system comprehensiveness; see Figure 1. Due to the limited scope of the article, only the second phase of the application of the ABC method, focused on the calculation of logistics costs, is presented in the following section.

In the first phase of implementation, the key activities of the company and cost objects were defined. The main criteria for identifying activities were the nature of the selected foundry, which focuses on piece production with a high proportion of manual labour. The analysis of the technological process identified 18 primary activities covering the main production operations (e.g. core production, moulding, casting removal, finishing of castings, separation of sprues and risers, blasting, annealing, grinding, inbound logistics - purchasing, production logistics, output logistics - dispatch, etc.). In addition, support activities necessary for the operation and infrastructure of the business were identified that could not be attributed to primary activities. These activities were grouped into 7 support activities, including for example metallurgical and technological preparation, personnel activities, economic activities, maintenance, etc. Finally, the cost objects were identified as: specific product (casting), material (kg), order, and customer.

The assignment of costs to activities represented the next stage of the model development, aimed at quantifying the costs generated by each activity. The total costs of the company were broken down into direct, payroll, variable and fixed costs. Direct costs are allocated to cost objects in the final phase of implementation. Payroll and variable costs are allocated to primary activities, while fixed costs are assigned to support activities. Cost data from the accounting system, classified by type, including analytical accounts and centres, is imported into specialised software, where it is broken down by activity. The subsequent transformation of costs into calculated costs is carried out through the so-called activity cost matrix. Costs are assigned to activities based on a relational variable called the Resource Cost Driver, which enables direct assignment where there is a real link between the cost and the activity. The outcome of this matrix is a quantification of the total indirect costs allocated to each activity, the so-called cost pool. The next step involved allocating costs to support activities that cannot be directly assigned to cost objects, as their outputs are utilised by the primary activities. Fixed costs were allocated to support activities based on cost relationship variables using the application in the software, the so-called activity cost matrix [14].

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The costs assigned to each activity are subsequently allocated to individual cost objects such as castings, materials, orders, and customers. For this purpose, it is necessary to measure the performance of activities and to express the relationship between activity costs and the cost object through metrics. This is done by using relational variables known as Activity Cost Drivers (ACD), which represent the causal factors influencing the cost of an activity and provide a metric for evaluating the performance of that activity. ACDs need to be quantifiable to accurately measure their impact. In collaboration with the consulting firm and the company's technical staff, relational variables for primary and secondary activities such as time (minutes), gross weight, and raw weight, were defined. The consumption of each activity was also quantified, for example, setting standards for time consumption in selected operations.

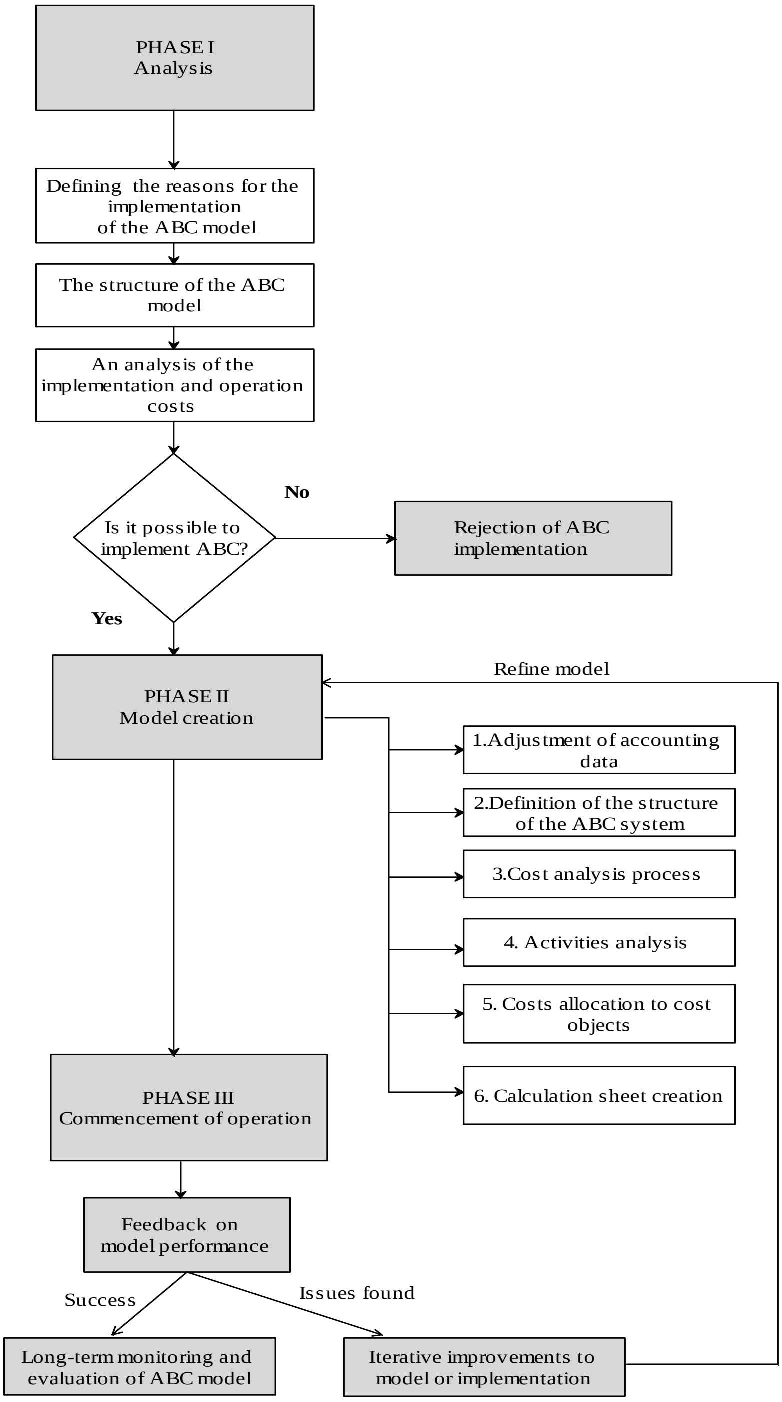

Figure 1 Methodology of implementation of the method ABC [modified by 11,13]

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Based on the quantification of Activity Cost Drivers (ACD), a measure of the performance of each activity, referred to as the Activity Recovery Rate (ARR), was established. Subsequently, the unit cost of the activities, referred to as the Activity Primary Rate (APR), was calculated, which allowed the cost per unit of the activity to be determined. The APR is determined as the ratio between the total cost (Cost Pool) and the ARR. This procedure resulted in the derivation of primary activity unit costs, referred to as the Primary Activity Rate (PAPR). Similarly, the procedure for calculating the APR for secondary activities was applied to obtain the secondary activity unit cost (SAPR) [14].

The final step in the allocation of overhead costs per product (1 piece of casting) is the allocation of logistics activity costs, which is done through different cost objects and allocation keys, as shown in Figure 2. This process involves quantifying the amount of logistics activities consumed by a specific cost object (product, material, order). Based on the product of the quantity of logistics activities consumed and the unit costs, the total logistics costs of a given cost object can be calculated. The enterprise determines for each cost object which logistics activities it uses and identifies criteria (e.g., standards, technological procedures, qualified estimates) that automatically quantify the consumption of activity units (min, kg, pcs).

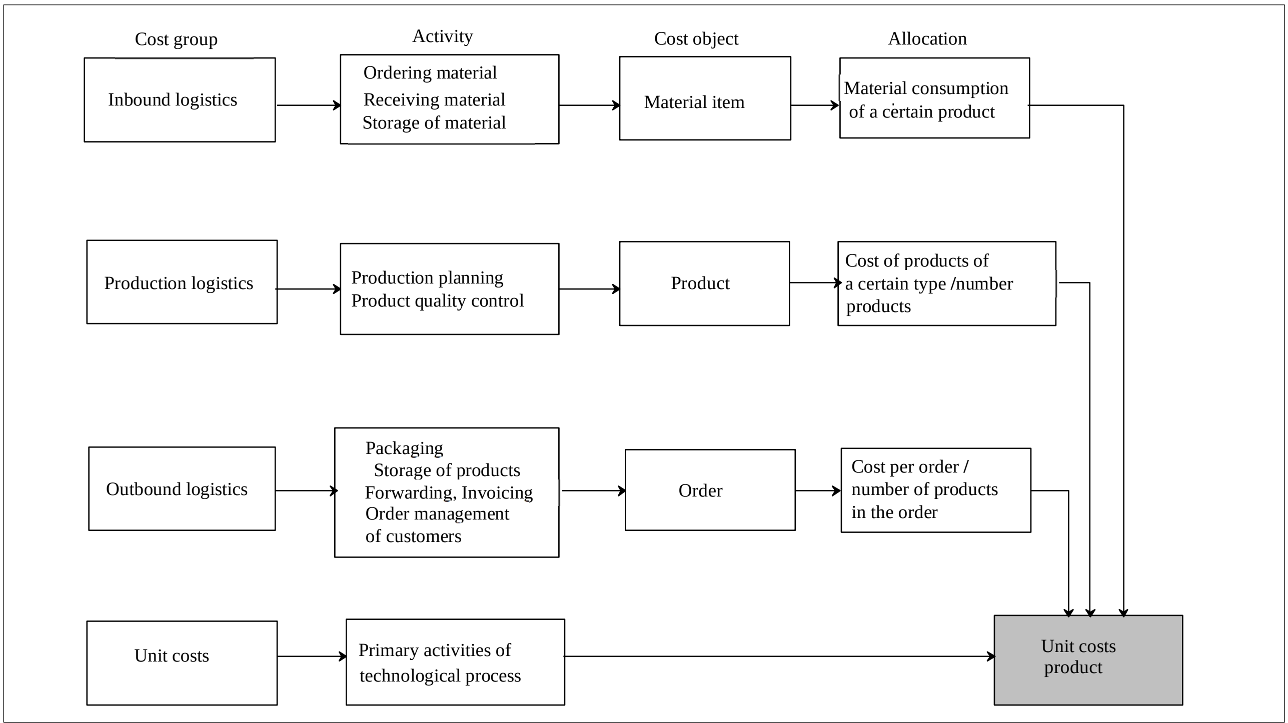

Figure 2 Allocation of logistics activity costs to cost objects and per product (own source)

4 Results and discussion

This chapter presents the main results of a case study conducted in a foundry company in the Czech Republic. One of the key outputs of the research was the development of a costing formula that enabled detailed allocation of logistics costs. The main benefits of the implementation of the ABC calculation method for logistics process management are summarized. The chapter also shows how this costing method has been specifically used in the analysis of customers and has enabled the differentiation of logistics service levels according to their economic benefits.

The aim of the application of the ABC method was to develop a new costing system, the output of which is the design of a costing sheet for a product (casting). ABC is a full costing method that includes not only direct costs but also activity costs, including the costs of logistics activities. The structure of the proposed costing sheet in abbreviated form, is shown in Table 1, where the calculation of the full cost of ownership per 1 piece of casting is provided. The cost was calculated as the product of the amount of units consumed (ARR) and the total unit cost (TUC), which is divided into the unit direct cost (UDC) and the unit cost of primary activities and secondary activities (PAPR, SAPR).

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Table 1 The structure of a casting costing sheet in abbreviated form in € (own source)

Casting (1pc)		ARR	ACD	TUC	UDC	PAPR	SAPR	Total
Direct costs	Material	14.50	kg	**8.50**	8.50			**123.25**
Activities								
F110	Cores production 3165	23.20	min	**5.50**		5.00	0.50	127.60
F500	Knocking out castings	15.00	min	**2.30**		2.10	0.20	34.50
Total direct costs + activity costs								**285.35**
Logistics activities								
L100.1	Acceptance of the customer's order	1.20	min	**0.50**		0.40	0.10	0.60
L200.1	Internal quality control	2.20	min	**0.90**		0.65	0.25	1.98
L200.2	Product packaging	4.10	min	**1.20**		0.95	0.25	4.92
Total direct costs + activity costs + logistics costs								**292.85**

The ABC costing method is primarily designed to accurately calculate the cost of a specific cost object. Thanks to its specific characteristics, it is also a key cost management tool that enables not only cost reduction but also cost optimisation. The benefits of implementing the ABC method in the logistics management of a foundry can be summarized in the following points:

- Precise allocation of logistics costs to a specific cost object.
- Determination of the actual costs of individual logistics activities.
- Efficient logistics cost management through a new costing method that determines the actual profitability of products and provides information on cost drivers.
- Identification of unused resource capacity.
- Providing information for decision-making throughout the product life cycle.
- Ability to evaluate the profitability of individual product lines and identify those that generate losses.
- Supporting effective decision-making on changes in order volume.
- Providing relevant information for the evaluation of suppliers and customers.
- Continuous monitoring of the development of logistics costs, identification of deviations and analysis of their causes.
- Positive impact on company culture, especially in the area of internal communication.
- Expanding the management information base for decision making at different levels of management.

The result of the application of the ABC calculation method was not only the creation of a calculation formula that enabled a more accurate allocation of logistics costs, but also the identification of specific benefits of this method for logistics management in a foundry company. The implementation of this method contributed to more efficient management of logistics processes at all levels, which included accurate tracking of costs of individual activities as well as decision support in key areas. One of these areas that was key to improving service and optimising resources was the logistics services provided to customers. Therefore, the Activity-Based Costing method was also used in the analysis of customers, which enabled differentiation of logistics service levels based on their economic benefits.

Differentiation of logistics service levels based on customer analysis

Customer analysis is one of the key components of logistics processes. It is essential for strengthening customer relationships and for adequately differentiating the level of logistics services provided in order to maximise customer satisfaction. Not all customers bring the same economic benefits to a business. Even for similar products, specific customer requirements can vary considerably, affecting not only the logistics chain but also the logistics costs. The differentiation of logistics services should therefore be based on a detailed customer analysis. This analysis focuses on key metrics that reflect the importance of the customer, such as revenue share, profit contribution share and other relevant metrics.

Pareto analysis, based on the Pareto's 80/20 principle, is a suitable tool for classifying the importance of customers. This principle states that approximately 80% of the effects result from 20% of the causes. In practical application, this means that most problems can be attributed to just a few key factors. Thus, Pareto analysis allows for the identification of these key factors and the focusing of efforts on resolving them, resulting in maximum improvement with minimum effort. A graphical tool called a Pareto diagram is used to visualize the results of Pareto analysis. This diagram is used to visually illustrate which causes have the greatest impact and how significantly they contribute to the overall problem. In the Pareto chart, the bars are arranged according to the importance of each category (e.g., sales, profit) from the most important to the least important. The Lorenz curve shown in the diagram represents the cumulative percentage of the total values of these categories [6].

The research focused on the application of the Activity-Based Costing method in logistics management in the foundry industry, resulting in the creation of a complex

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costing formula for detailed allocation of logistics costs. As a further example of the practical application of this costing method, an analysis of customers based on their 'contribution to profit' was carried out, demonstrating its ability to accurately cost both jobs and individual customers. The 'profit contribution' indicator includes the contribution to fixed costs and profit generation. The profit calculation was based on the Activity-Based Costing method applied in the company. This method allows not only costs to be allocated to individual cost objects, but also revenues. Thanks to the precise allocation of costs, it is possible to determine the profit generated by individual cost objects relatively accurately. The principles of the Activity-Based Costing method consider the customer as the main cost object because they are based on the assumption that the firm's revenues are generated by customers, not products. The profit of a cost object was determined as the difference between the revenue from that object and the direct costs and expenses of the activities associated with that object. In the first step, the amount of profit contribution for each customer was calculated for the observed period. Customers were then ranked in descending order of their contribution to profit, and the cumulative shares of their total contribution were calculated to profit, as shown in Table 2.

A Pareto diagram was created as part of the analysis (Figure 3). The data in Table 2 and the Pareto chart indicate that the key customers in terms of share of total profit contribution are B, D and F, which together account for 52% of the total profit contribution of €35 750. Customer B contributes 20% of the profit and is thus the most important customer. Although all customers contribute to profits, their returns gradually decrease. Based on the Lorenz curve (Figure 3), it can be concluded that the "vital minority", which represents 80% of the profit contribution, includes customers B, D, F, A and C. The second group, representing 20%, includes customers G, H and E.

Table 2 Pareto analyse of customers (own source)

Customers	**Profits of orders (€)**	**Cumulative profits (€)**	**Structure (%)**	**Cumulative structure (%)**
B	7 050	7 050	20	20
D	5 950	13 000	17	37
F	5 500	18 500	15	52
A	5 300	23 800	15	67
C	4 850	28 650	13	80
G	3 200	31 850	9	89
H	2 800	34 650	8	97
E	1 100	35 750	3	100
SUM	35 750		100	

Profitability analysis provides detailed information on the real added value of individual customers. This information enables the elimination of high-loss performances and thus contributes to an increase in the overall profit achieved. It also allows differentiation of the level of logistics services according to the specific needs of individual customers.

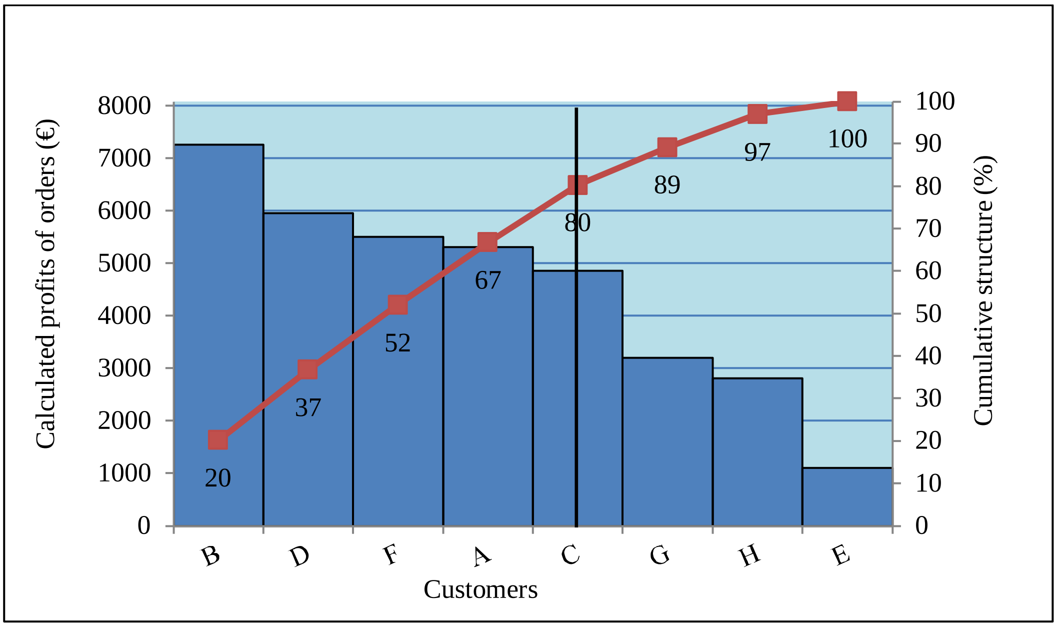

Figure 3 Customer Pareto analysis and Lorenz curve (own source)

The application of Activity-Based Costing in the management of logistics costs in foundry production has produced a number of significant results. A key benefit was the accurate allocation of logistics costs to activities, which enabled a better understanding of the economic efficiency of logistics processes and a detailed overview

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of the actual costs of individual activities. This concept allowed detailed identification of cost factors that were often part of overhead costs in traditional costing systems. Higher levels of cost transparency and more accurate performance measurement of logistics processes have created the basis for strategic decisions and the introduction of technological innovations. Key benefits of the implementation include improved planning of logistics operations, such as warehousing processes and optimization of supply routing, as well as the discovery of unused capacity and the possibility of redirecting resources to higher value-added activities, etc. Another advantage was the introduction of differentiation of logistics service levels according to the contribution of customers to overall profit, which contributed to more effective management of key customer relationships.

Although the study had important contributions, it had limitations affecting its generalisability and the accuracy of the results. The introduction of the ABC method was time and data consuming, as it required a detailed analysis of logistics processes. In this study, some of the data were obtained through educated guesses, which may have affected the accuracy of some of the conclusions. Another challenge has been the complexity of the system, which includes staff training and the adoption of a new culture in process management. This transition can pose a significant challenge, especially for smaller businesses that are faced with limited human and financial resources. Furthermore, the results of this case study are specific to custom foundry manufacturing and may require adjustments for application in other industries.

The implementation of the ABC method has been challenging but has opened up new opportunities for innovation in logistics cost management and process optimization. One possible approach is to implement advanced technologies, such as software tools that allow automation of data collection and computation, which would reduce time and increase accuracy. The ABC method allows you to identify cost-consuming logistics activities and then optimise them in a targeted way through lean manufacturing or digital technologies. Detailed information on the costs of logistics activities can contribute to better planning and management of the entire supply chain. The ABC method also makes it easier to identify areas for reducing the environmental impact of logistics processes, for example by optimising transport, thereby contributing to business sustainability.

Based on the results obtained from this study, the following directions for future research can be recommended. One of which is the analysis of the long-term impacts of the implementation of the ABC method on the profitability and efficiency of business processes, with a focus on logistics costs. Another recommendation is to compare the effectiveness of the ABC method with other modern costing methods, such as Time Driven Activity-Based Costing, in relation to logistics process management. The linking of the ABC method with advanced technologies such as predictive models for logistics process management is also an interesting research direction.

5 Conclusions

The evolution of the business environment has brought changes in the structure of logistics processes and in the characteristics of supply chains, which has led to an increase in the differentiation of logistics costs. The complexity of cost relationships and drivers has reached a level where traditional cost management methods no longer provide sufficient information, creating the need for new, sophisticated systems [15,16]. In this context, the ABC method appears to be an effective tool for managing and allocating logistics costs.

The aim of the research was to apply the ABC method for logistics cost management in foundry companies and to investigate its potential in optimizing logistics processes. The case study focused on the application of the ABC method in the calculation of logistics costs in foundry production. The stated objective was achieved through the presentation of the individual steps of the method implementation and the creation of a costing sheet for the quantification of logistics costs.

The results of the research confirmed that the outputs of the ABC method have a wide application in the optimization of logistics processes. The method was successfully used to differentiate the level of logistics services based on the analysis of the profitability of individual customers according to the "Contribution to profit" indicator. Costs were allocated to individual contracts, which allowed the profit to be determined at the contract level. Pareto analysis and Lorenz curve were used to assess the significance of individual customers.

Finally, the study highlighted the significant benefits of implementing the ABC method, including accurate allocation of logistics costs to individual activities, improved transparency of cost structures and more efficient planning and decision-making in logistics operations. Moreover, the differentiation of logistics services based on customer profitability confirmed the practical use and value of this method.

However, the study also identified some limitations, such as the time and data complexity of implementing the ABC method and the dependence on some estimators, which may have affected the accuracy of the results. Moreover, the focus on custom foundry production limits the generalisability of the findings to other sectors.

Despite these limitations, the ABC method offers considerable potential for innovation, including automation of data collection and process optimization through advanced digital technologies. These capabilities underline its importance in modernising logistics management in the foundry industry.

Based on the results of the study, the following directions for future research can be recommended: focus on analysing the long-term impacts of the ABC method on

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the profitability and efficiency of logistics processes and compare its effectiveness with alternative calculation approaches such as Time-Driven ABC.

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