Accounting 12 (2026) 89–102

Contents lists available at GrowingScience

Accounting

homepage: www.GrowingScience.com/ac/ac.html

Application of throughput accounting in production mix decisions for a small metallurgical enterprise

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C H R O N I C L E

Article history:
Received July 23, 2025
Accepted October 26 2025
Available online
October 26 2025

Keywords:
Production Mix
Absorption Costing
Theory of Constraints
Throughput Accounting
Micro and Small Enterprises

A B S T R A C T

Micro and Small Enterprises are a critical catalyst for socio-economic development in Brazil. However, financial and technical limitations frequently hinder the access and implementation of management tools by Micro and Small Enterprises. This study addresses this challenge through a case study that applies the Throughput Accounting to determine the most profitable production mix for the small enterprise Bianfer Indústria Metalúrgica. The company manufactures and commercializes parts and components for agricultural machinery and equipment in Brazil. Production mix decisions are currently based on the owners' experience, sales history, and Absorption Costing. This approach, however, generates additional costs and inventory thereby compromising the profitability of Bianfer Indústria Metalúrgica. The pursuit of enhanced profitability led to the formulation of three hypothetical scenarios to compare the production mix proposed by Absorption Costing and Throughput Accounting concerning the Return on Assets (ROA). Mathematical modeling and scenario simulations were conducted using the Microsoft Office Excel 365. The results indicate that Throughput Accounting is readily adaptable, solves the problem more quickly, and provides superior financial gains (ROA from 1.36% to 2.71%). This study addresses an important practical gap that can guide students, professionals, and researchers in the application of Throughput Accounting. The main contribution of this study is empirical evidence that Throughput Accounting is an effective management tool for Micro and Small Enterprises. The implementation of Throughput Accounting through a simple Microsoft Office Excel model can significantly improve production mix decision-making in Micro and Small Enterprises.

1. Introduction

The demand for management tools that enable faster, more assertive, and optimized decision-making has recently increased (Pinto et al., 2018; Hegazi, 2024; Liang, 2025). However, advancements in this regard have principally targeted large enterprises and frequently remain inaccessible to Micro and Small Enterprises (MSEs). The issue is that financial (high costs) and technical (complexity) limitations frequently hinder the access and implementation of management tools by MSEs (Curado et al., 2022; Franczak & Weinzimmer, 2022). Many MSEs face challenges such as a lack of specialists, technical inability of entrepreneurs, financial and/or capital access restrictions, and low differentiation related to the production sectors (refer to Galli-Debicella (2021), Padilla-Ospina et al. (2021), Curado et al. (2022), and Franczak and Weinzimmer (2022)). Therefore, it is essential to focus on the use of simple management tools for defining the production

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ISSN 2369-7407 (Online) - ISSN 2369-7393 (Print)

doi: 10.5267/j.ac.2025.10.001

mix in MSEs. Most of these companies address such issues by using Absorption Costing (AC) from Traditional Cost Accounting (TCA).

A general analysis points to AC as a straightforward method required by the laws of many countries and is, therefore, the most widely utilized for planning and decision-making in MSEs (Ramanujam, 1986; Noreen et al., 1995; Vieira et al., 2019). This method stipulates that all fixed and variable costs (direct and indirect), including production losses, must be allocated to the units of products or services produced (Lin, 2020; Gutiérrez, 2021; Buys, 2024). An increase in production volume reduces unit costs and allocates a portion of the fixed costs to inventory (work-in-progress or finished product) to prevent an impact on the period's result (Noreen et al., 1995; Buys, 2024). However, the limitations of the AC regarding unit costs can lead to errors that result in suboptimal decisions thereby impairing the competitiveness of MSEs. There are issues related to the cost allocation criteria, the contribution margin, system inefficiencies transferred to product costs, and the inability to determine what, when, and how much to produce (refer to Goldratt (1990), Dugdale and Jones (1997), Lockamy (2003), Ikeziri et al. (2019), Gutiérrez (2021), Ojra et al. (2021), García-Vidal et al. (2023), Buys (2024), and Liang (2025)).

A managerial alternative derived from the Theory of Constraints (TOC) and proposed in the book *The Goal*, published by Goldratt and Cox (1984), is Throughput Accounting (TA). This is a philosophy that offers a critical perspective on TCA; instead of controlling "Cost," it aims to protect "Gain" (Goldratt, 1984; Corbett, 1999; Cox et al., 2012). Thus, operating expenses are simply resources for generating profit (Goldratt, 1984; Goldratt, 2010). Decisions about the production mix consider direct materials as variable costs and inventories and fixed costs as operational expenses that constitute obstacles to profitability (Goldratt, 1990; Corbett, 1999). In essence, TA aims to identify and eliminate constraints that hinder the performance of complex systems by implementing straightforward measures that enhance profitability and competitiveness (Smith, 2000; Draman et al., 2012; Watson et al., 2012). An important theoretical framework is provided by Goldratt (1984), Goldratt (1990), Luebbe and Finch (1992), Plenert (1993), Lee and Plenert (1996), Gupta (2001), Mabin & Balderstone (2003), Gupta and Boyd (2008), Gupta et al. (2010), Naor et al. (2013), Simsit et al. (2014), Orouji (2016), Zhuang and Chang (2017), Ikeziri et al. (2019), Lueg and Ilieda (2024), and Ramesh and Sumitra (2024)).

However, effective decision-making in the current competitive landscape requires complementary information generated by management or optimization tools that consider the limitations of production capacity relative to business profitability (Gutiérrez, 2021; Szukits & Moricz, 2024; Liang, 2025). In this context, this study aims to apply TA to determine the production mix for the small metallurgical enterprise called Bianfer Indústria Metalúrgica. The enterprise is engaged in the manufacturing and commercialization of parts and components for agricultural machinery and equipment and is installed in the city of Jaú, in the state of São Paulo (SP), Brazil. Decisions regarding the production mix are based empirically (on the partners' experience), along with sales history and indicators from the AC method of TCA. This is corroborated by the fact that Brazilian law adopts AC as the mandatory method for determining companies' taxable income through Law Nº. 6,404 of 1976. However, the entire scope of this study is to improve the processes of analysis and managerial decision-making to maximize the profitability of Bianfer Indústria Metalúrgica. We emphasize that the focus of this study is not to address other well-established methods such as Variable Costing (VC), Activity Based Costing (ABC), and Production Effort Units (UEP). The analysis concentrates on the comparison of the results obtained by AC and TA in three different hypothetical scenarios for defining the production mix for the Class A products of the ABC Curve. This study addresses key issues and helps fill the evident gap related to the demand for low-cost, less complex, and better-adapted management tools for the reality of MSEs in Brazil. Approximately 14 million MSEs play a crucial role in Brazil's economic development (Curado et al., 2022).

2. Research Methodology

This is applied research classified as a case study that employs a quantitative methodology (Haegeman et al., 2013; Matović & Ovesni, 2023). The study also presents a concise literature review based on a traditional search in the Scopus, IEEE Xplore, Web of Science, ScienceDirect, etc., databases. (Linenluecke et al., 2020; Donthu et al., 2021). The keywords used in the advanced searches, together with the Boolean expression "AND," were "mix," "costing methods," "cost accounting," "theory of constraints," and "throughput accounting." The selection and classification of publications were conducted through careful assessments of relevance and suitability to the study objective, covering the period from January 1980 to December 2024. The analysis led to the selection of 14 theoretical approaches and 34 practical applications related to TA techniques and methodologies. Subsequently, the collection and analysis of the enterprise's accounting and operational reports were carried out, including a detailed production process flow for the Class A products of the ABC Curve. This section also presents the mathematical models for implementing the AC and TA methods. The comparative analyses between AC and TA were conducted by simulating Hypothesis 1, Hypothesis 2, and Hypothesis 3. These hypotheses are based on an actual management environment and reflect the conditions at Bianfer Indústria Metalúrgica.

3. Literature Review

The publications by Goldratt (1984) and Goldratt (1988) introduced tools to eliminate the profitability limitations inherent in TCA. Luebbe and Finch (1992) compared the application of TOC and Linear Programming (LP). Patterson (1992) simulated two hypothetical cases to compare management accounting and TOC. Fredendall and Lea (1997) proposed a revised heuristic for situations in which optimal solutions were not achieved in defining the production mix using TOC. Hsu and Chung (1998) addressed the increase in yield for production mixes defined by TOC and obtained the same results as the Dual-Simplex Method. Coman and Ronen (2000) addressed an outsourcing problem and demonstrated that TOC is

superior to TCA and inferior to LP. Tollington and Wachter (2001) addressed aspects of management accounting in the Internet retail segment through TOC and ABC. Gupta et al. (2002) discussed the combination of TOC and Activity-Based Management (ABM). Mabin and Davies (2003) presented a study in which TCA approaches are complemented by TOC.

Mishra et al. (2005) addressed profit maximization through production mix in bottlenecked environments with product diversity by applying Tabu-Simulated Annealing (Tabu-SA) that combines Tabu Search (TS) and Simulated Annealing (SA). The performance of Tabu-SA proved to be superior to BT, RS, TOC, and Revised TOC (R-TOC). Bhattacharya and Vasant (2007) addressed product mix decision-making using a function called Smooth Logistic Membership (SLM). Chaharsoughi and Jafari (2007) proposed a SA that was shown to be as good as TS and the Genetic Algorithm (GA). Ray et al. (2008) proposed a flexible model for defining the production mix that combines TOC and the Laplace Criterion (LPC). Tsai et al. (2008) showed that identifying which products are more sensitive to changes in resource availability is more efficiently done using TOC. Wang et al. (2009) addressed the production mix problem with capacity constraints by applying the Immune Algorithm (IA). Linhares (2009) questioned the application of TOC to production mix definition through the problem addressed by Blackstone (2001).

Nazari-Shirkouhi et al. (2010) integrated product mix and outsourcing by proposing the Imperialist Competitive Algorithm (ICA). Ifandoudas and Gurd (2010) explored the importance of TOC in short- and long-term decision-making through four-year action research at AEM Australia. Utku et al. (2011) studied the disadvantages and benefits of defining the production mix using TOC and TCA. Mansourabad et al. (2012) addressed the optimal production mix under constant demand by applying TOC. Majeryak et al. (2013) studied TOC and compared TA with Managerial Accounting (MA). De Souza et al. (2013) proposed TOC, which, on average, proved to be more effective than Integer Linear Programming (ILP). Al-Beshtawi (2014) aimed to maximize the results of industrial companies by focusing on improving operations by applying TCA and TOC.

Islam (2015) used real data to show that the most appropriate management tool for production mix and demand fulfillment is TA. Hilmola (2016) focused on Blackstone's (2001) problem expanded by Linhares (2009) to demonstrate that TOC outperforms any approach when considering the Capacity Constraint Resource (CCR). Mehra et al. (2016) demonstrated that TOC improves manufacturing performance and presents better results than TCA. Sokolov and Elsukova (2016) presented a case study demonstrating that, for profitability and control purposes, TA can be complemented by ABC. Zhuang and Chang (2017) proposed a Mixed Integer Programming (MIP) based on Time-Driven Activity-Based Costing (TDABC) and demonstrated that MIP, oriented towards long-term profit, presents better results than TOC or ABC. Lutilsky (2018) addressed the importance of MA and, aiming at reducing costs and increasing profitability, applied TOC. Chen et al. (2020) considered the Revised Rank Comparison (RRC) to propose the Shifting Bottleneck-Driven TOC Heuristic (STOCh) for defining the production mix with multiple bottlenecks in a Chinese MSE. The analysis of the experiments showed that STOCh outperforms the TOC heuristics called RTOCh, TOC_AK, and TOC_SN. Jassem (2021) presented TA as an alternative approach to the distortions identified in TCA. Salman (2022) presented the advantages and disadvantages of applying TA and TCA for defining the production mix at Rogano enterprise for Insulating Glass and Aluminium in northern Iraq. More recently, Machado et al. (2023) addressed a complex and dynamic scenario using a System Dynamics (SD) model based on problem P and Q. Thereafter, analyses considering simultaneous variability in different parameters were conducted for decision-making using an Artificial Neural Network (ANN). This research fills a gap in the literature by presenting the robustness of the TA under stochastic conditions with the employment of SD and ANN.

The literature analysis shows an increase in publications starting in 1991 and a significant decline from 2021 to 2025. Another relevant finding is that studies simulating hypothetical scenarios (60%) still outweigh empirical studies in real environments (40%). Particular attention should be directed toward the decreasing interest in research, the issues involving the practical applicability of TA, and the scarcity of case studies in MSEs. Most approaches, therefore, focus on large companies and aim to conduct comparative analyses of methods used to define the production mix versus TA. The core debate centers on the advantages and limitations of the different proposed methods and the focus on cost reduction derived from TCA. A series of limitations is addressed by combining TA with the ABC method integrated with ABM or with MIP based on TDABC. The applications of LP marked an evolution by offering improved solutions to problems involving multiple constraints, while MIP proved more advantageous for long-term decision-making compared to ABC. Recently, literature has been dedicated to obtaining more robust solutions for complex and multifaceted dynamic environments, aiming to fill the gap and address the criticisms regarding TA. These studies have presented high-performance solutions through modeling and simulation (SD) and more complex optimization methods, which include machine learning (ANN), advanced heuristics (STOCh), and hybridized metaheuristics (Tabu-AS). However, the implementation complexity of these models may render them less accessible to firms with limited resources and technological infrastructure, particularly MSEs. Advances are expected through the integration of technologies such as big data, machine learning, and artificial intelligence, driven by progress in Computer Science (CS) and Information Technology (IT).

4. Method Application and Results Analysis

4.1 Bianfer Indústria Metalúrgica

This study addresses the problem of decision-making related to the production mix at Bianfer Indústria Metalúrgica. Bianfer is a small metalworking enterprise established in 2011 and situated in Jaú, São Paulo (SP), Brazil. The company specializes in the production and commercialization of parts and components (forged, machined, and stamped) for tractors, machinery,

and agricultural equipment. It operates throughout the national territory in a competitive market characterized by limited differentiation among production sectors in Brazil. The enterprise has adopted the Simples Nacional tax regime, with all tax, accounting, and labor-related services managed by an outsourced office in Jaú (SP). Management is centralized under the management partners, while strategic decisions are overseen by the Chief Executive Officer (CEO). The enterprise maintains a chart of accounts, and all accounting entries concerning direct and indirect production expenses are recorded in accordance with the organizational structure depicted in Figure 1.

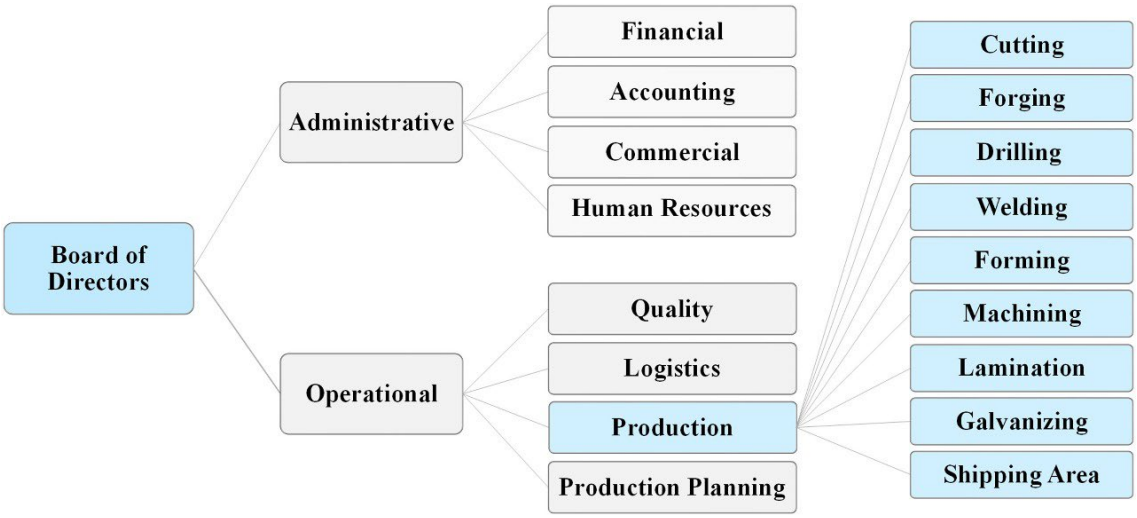

Fig. 1. Organizational structure of Bianfer Metallurgical Industry

Figure 1 demonstrates that the enterprise's organizational structure is divided into two departments called Administrative and Operational. All sales, inventory, and production controls are performed by employees using licensed software and Microsoft Office Excel 365. There is a variety of products classified into 16 families, with a total of items in the sales catalog exceeding 1,200 Stock Keeping Units (SKUs). The following families represent 80% of the enterprise's production: i) Plain Pin; ii) French Screw; iii) Hex Screw. The manufacturing process of the SKUs with the highest revenue share at Bianfer Metalworking Industry is illustrated in Fig. 2.

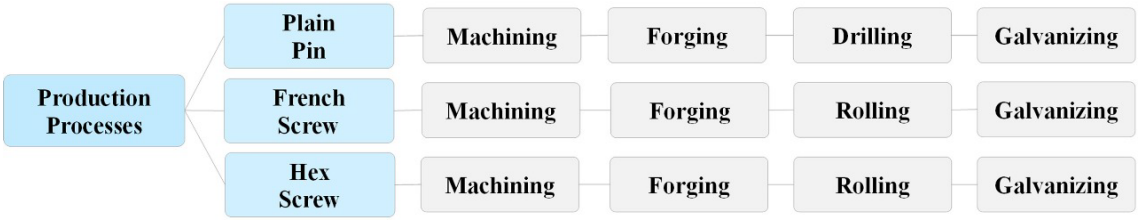

Fig. 2. Example of the production process of the main product families

Fig. 2 demonstrates that all products go through the same process until "Forging." After this stage, the products are directed to the process sequences corresponding to each family of the different types of SKUs. Production activities are carried out by 12 employees, who are allocated according to the operational needs of the area designated as "Production." This rotation of labor complicates and compromises the accurate measurement of man-hour cost for each process within "Production." All data is obtained from a TCA system, and, at the end of each period (monthly), product costs are determined using the AC. These costs are subdivided into three groups (labor, consumable material, and general manufacturing expenses) and classified as direct and indirect. Process analyses and improvements focus on cost reduction and the production efficiency rate in "Production." However, decision-making about the production mix is basically based on orders in the portfolio and the experience of managers, without the use of scientific methods, such as TOC. There is a clear demand for a more effective management system for decision-making in defining the product mix of Bianfer Indústria Metalúrgica.

4.2 Application of Absorption Costing

This section presents the mathematical modeling for the AC method employed by Bianfer Indústria Metalúrgica. In the AC, the production mix of n SKUs of finished product is represented by the set $TP_{mix} = \{P_1, P_2, ..., P_n\}$, and the subscript j, $\forall j = (1, 2, ..., n)$, denotes the j-th P_n. Thus, Pt_j is the total production quantity of each P_j that makes up the mix of SKUs in TP_{mix}. The raw materials used in production and in stock at time t are referred to as $RM = \{M_1, M_2, ..., M_n\}$, which the subscript i, $\forall i = (1, 2 ..., n)$, denotes the i-th M_i. The M_n are measured in kilograms (kg), and each P_j consumes only one M_i. The quantity of M_i consumed by P_j is denoted by MPt_{ij}, and the total quantity of M_i demanded by TP_{mix} is defined by $TMTP$. MPt_{ij} is obtained by Expression 1, and $TMTP$ by Expression 2.

$$MPt_{ij} = Pt_j \times kg_{ij} \quad (1)$$

$$TMTP = \sum_{j=1}^{n}\sum_{i=1}^{n} MPt_{ij} \quad (2)$$

The percentage of MPt_{ij} in TP_{mix} is given by MPp_{ij}, and the average unit cost of M_i is denoted by CM_i. Furthermore, the cost of MPt_{ij} is denoted CMt_{ij}, and $TCRM$ refers to the total cost of M_i in TP_{mix}. Next, MPp_{ij} is calculated by Equation 3, while Expressions 4 and 5 measure CMt_{ij} and $TCRM$.

$$MPp_{ij} = \left(\frac{MPt_{ij}}{TMTP}\right) \times 100 \quad (3)$$

$$CMt_{ij} = CM_i \times MPt_{ij} \quad (4)$$

$$TCRM = \sum_{i=1}^{n}\sum_{j=1}^{n} CMt_{ij} \quad (5)$$

Next, Indirect Variable Costs (IVC) and Indirect Fixed Costs (IFC) are allocated proportionally to each P_j based on $MPp_{i(j),j}$, where $i(j)$ is the index of the M_i consumed by P_j. Equations 6 and 7 calculate the Total Variable Cost (VCt_j) and the Total Fixed Cost (FCt_j). Expressions 8 and 9 measure the Total Production Cost (TCp_j) of P_j and the Total Manufacturing Cost ($TCTP$) of TP_{mix}. Next, the application of AC, assuming a unit cost of US$ 13.96 for a specific M_i, is exemplified by Table 1.

$$VCt_j = IVC \times \frac{MPt_{i(j),j}}{TMTP} \quad (6)$$

$$FCt_j = IFC \times \frac{MPt_{i(j),j}}{TMTP} \quad (7)$$

$$TCp_j = CMt_{i(j),j} + VCt_j + FCt_j \quad (8)$$

$$TCTP = \sum_{j=1}^{n} (CMt_{i(j),j} + VCt_j + FCt_j) \quad (9)$$

Table 1
Determination of the total costs of raw materials and products in the production mix

Product Code (P_j)	Prod. Mix Defined (Pt_j)	Weight of M_i (kg_{ij})	Weight in Pt_j (MPt_{ij})	Pct. (%) of MPt_{ij} (MPp_{ij})	Total Cost M_i in Pt_j (CMt_{ij})	Total Var. Cost - Pt_j (VCt_j)	Total Fixed Cost - Pt_j (FCt_j)	Total Cost in TP_{mix} (TCp_j)
2511	680	1.94	1,319.20	16.46%	18,416.03	11,818.90	6,904.96	37,139.89
3005	2,824	0.38	1,073.12	13.39%	14,980.75	9,660.06	5,643.70	30,284.51
2513	842	1.27	1,069.34	13.34%	14,927.98	9,598.45	5,607.71	30,134.14
3003	1,052	0.89	936.28	11.68%	13,070.46	8,398.64	4,906.74	26,375.84
3302	3,163	0.24	759.12	9.47%	10,597.31	6,761.07	3,950.02	21,308.40
3007	2,198	0.32	703.36	8.77%	9,818.90	6,298.98	3,680.06	19,797.94
3301	2,317	0.24	556.08	6.94%	7,762.87	4,894.48	2,859.50	15,516.85
3358	1,613	0.24	387.12	4.83%	5,404.19	3,447.42	2,014.09	10,865.70
1859	1,479	0.24	354.96	4.43%	4,955.24	3,161.65	1,847.13	9,964.02
3419	1,138	0.24	273.12	3.41%	3,812.75	2,432.04	1,420.87	7,665.66
3518	1,132	0.24	271.68	3.39%	3,792.65	2,419.88	1,413.77	7,626.30
3552	731	0.24	175.44	2.19%	2,449.14	1,562.59	912.91	4,924.64
3433	575	0.24	138.00	1.72%	1,926.48	1,228.18	717.54	3,872.20
Tot./Avg.	**19,744**	**0.41**	**8,016.82**	**100.00%**	**111,914.77**	**71,682.34**	**41,879.00**	**225,476.11**

The Unit Cost (UC_j) of P_j is then calculated according to Equation 10 and used by managers as the basis for defining the Sales Price (SP_j). Thus, Expressions 11 and 12, respectively, determine the Gross Profit (GP_j) and the Profit Margin (PM_j) per P_j of TP_{mix}. Subsequently, these calculations are exemplified in Table 2.

$$UC_j = \left(\frac{TCp_j}{Pt_j}\right) \quad (10)$$

$$GP_j = SP_j - UC_j \quad (11)$$

$$PM_j = \left(\frac{GP_j}{SP_j}\right) \times 100 \quad (12)$$

Table 2
Determination of the unit cost and gross profit per product in the production mix

Product Code (P_j)	Prod. Mix Defined (Pt_j)	Weight in Pt_j (MPt_{ij})	Pct. (%) of MPt_{ij} (MPp_{ij})	Total Cost in TP_{mix} (TCp_j)	Avg. Cost Unit. - P_j (UC_j)	Selling Price (SP_j)	Unit Gross Profit - P_j (GP_j)	Profit (%) Margin (PM_j)
1859	1,479	354.96	4.43%	37,139.89	6.74	41.50	34.76	83.77%
2511	680	1,319.20	16.46%	37,139.89	54.62	61.29	6.67	10.89%
3419	1,138	273.12	3.41%	30,284.51	6.74	23.59	16.85	71.45%
2513	842	1,069.34	13.34%	30,134.14	35.79	54.31	18.52	34.10%
3007	2,198	703.36	8.77%	26,375.84	9.01	12.97	3.96	30.55%
3358	1,613	387.12	4.83%	21,308.40	6.74	21.00	14.26	67.92%
3433	575	138.00	1.72%	19,797.94	6.73	33.49	26.76	79.89%
3552	731	175.44	2.19%	15,516.85	6.74	18.61	11.87	63.80%
3302	3,163	759.12	9.47%	10,865.70	6.74	13.70	6.96	50.83%
3003	1,052	936.28	11.68%	7,665.66	25.07	37.33	12.26	32.84%
3518	1,132	271.68	3.39%	7,626.30	6.74	12.10	5.36	44.32%
3301	2,317	556.08	6.94%	4,924.64	6.70	11.40	4.70	41.25%
3005	2,824	1,073.12	13.39%	3,872.20	10.72	16.90	6.18	36.54%
Tot./Avg.	**19,744**	**8,016.82**	**100.00%**	**225,476.09**	**11.42**	**22.35**	**10.93**	**48.91%**

Table 1 and Table 2 demonstrate the sequence of application of the AC method for a given TP_{mix} processed by Bianfer Indústria Metalúrgica. This TP_{mix} corresponds to Class A products (representing 80% of the enterprise's production) from the ABC Curve. The tables are self-explanatory and initially present the volume of P_{tj}, that is, the quantity of each SKU produced in the different TP_{mix} production orders. The quantity in kg_{ij} is obtained from the technical file of each P_j, and the indirect costs are apportioned according to the MPt_{ij}. It is important to highlight that IVC and IFC are extracted from a TCA system. In addition, the costs related to productive labor, since employees work in different processes in the "Production" area, are classified as IVC. It is also possible to verify that SP_j is calculated based on the UC_j derived from the TCp_j. The calculation of GP_j and PM_j assists managers in the decision-making process of the TP_{mix} and in the preparation of the Income Statement (P&L).

4.3 Application of Income Accounting

This section details the entire mathematical modeling and application of TA at Bianfer Indústria Metalúrgica. Technically, TA was introduced as an alternative method to achieve the profitability goals established by Bianfer Indústria Metalúrgica. The modeling starts with the production sectors of the "Production" area, represented by the set $PS = \{S_1, S_2, ..., S_8\}$. Thus, each sector is denoted by S and the subscript y, $\forall y = (1, 2 ..., 8)$, denotes the y-th S_y. The analysis identified S_2 (Forging) as the Capacity Constraint Resource (CCR). In S_2, there are two machines that work 22 working days per month in 8-hour daily shifts, using 90% of the CCR capacity. Expression 13 calculates the Effective Capacity (ECr_s) in minutes (min) of S_2 or CCR.

$$ECr_2 = Dw \times Hw \times Nm \times 60 \times \frac{ECp_2}{100} \tag{13}$$

where Dw are the working days of the month, Hw represents the hours worked per day, Nm denotes the number of machines, and ECp_2 is the effective capacity (in percentage) of S_2. Moreover, if only direct material is considered as VCt_j, then, given SP_j, expression 14 calculates the Unit Gain (UG_j) of P_j.

$$UG_j = SP_j - VCt_j \tag{14}$$

Expression 15, given the Product Time in the CCR (PTr_j), calculates the Unit Gain Rate (UGr_j) of each P_j. Next, expression 16 measures the Total Production Gain ($TGTP$) for TP_{mix}.

$$UGr_j = \left(\frac{UG_j}{PTr_j}\right) \tag{15}$$

$$TGTP = \sum_{j=1}^{n} TGr_j \tag{16}$$

Hence, expression 17 calculates the Total Product Time in CCR (TTr_j) using the Demand Forecast (DF_j) of P_j. Expression 18 determines the Total Product Gain in CCR (TGr_j), and equation 19 provides the production schedule based on the Percentage of P_j in CCR Capacity (PPr_j). Next, Table 3 presents an example of the application of TA that encompasses TGr_j and extends to the production schedule based on PPr_j.

$$TTr_j = DF_j \times PTr_j \quad (17)$$

$$TGr_j = TTr_j \times UGr_j \quad (18)$$

$$PPr_j = \left(\frac{TTr_j}{\sum_{j=1}^{n} TTr_j}\right) \times 100 \quad (19)$$

Table 3
Determination of unit and total gains per product in the production mix

Product Code (P_j)	Demand Forecast (DF_j)	Selling Price (SP_j)	Variable Cost (VCt_j)	Unit Gain (UG_j)	Time in CRR (PTr_j)	Gain in CRR (UGr_j)	Total Time in CRR (TTr_j)	Total Gain in CRR (TGr_j)	Pct. (%) in CRR (PPr_j)	Acc. Pct. in CRR (APr_j)
1859	1,479	41.50	3.35	38.15	0.967	39.45	1,430.19	56,423.26	7.52%	7.52%
3005	2,824	16.90	5.30	11.60	0.967	11.99	2,730.81	32,744.85	14.37%	21.89%
3302	3,163	13.70	3.35	10.35	0.950	10.89	3,004.85	32,735.79	15.81%	37.70%
2513	842	54.31	17.73	36.58	0.900	40.65	757.80	30,801.04	3.99%	41.68%
3358	1,613	21.00	3.35	17.65	0.983	17.95	1,585.58	28,468.81	8.34%	50.03%
3003	1,052	37.33	12.42	24.91	0.933	26.69	981.52	26,200.70	5.16%	55.19%
2511	680	61.29	27.08	34.21	0.950	36.01	646.00	23,261.17	3.40%	58.59%
3419	1,138	23.59	3.35	20.24	0.983	20.59	1,118.65	23,032.67	5.88%	64.47%
3007	2,198	12.97	4.47	8.50	0.967	8.79	2,125.47	18,689.16	11.18%	75.65%
3301	2,317	11.40	3.35	8.05	0.967	8.32	2,240.54	18,650.93	11.79%	87.44%
3433	575	33.49	3.35	30.14	0.967	31.17	556.02	17,330.27	2.93%	90.37%
3552	731	18.61	3.35	15.26	0.983	15.52	718.57	11,154.77	3.78%	94.15%
3518	1,132	12.10	3.35	8.75	0.983	8.90	1,112.76	9,904.55	5.85%	100.00%
Tot/Avg.	**19,744**	**22.35**	**5.67**	**16.68**	**0.963**	**17.33**	**19,008.76**	**329,397.95**	**100.00%**	**100.00%**

Table 3 demonstrates the PTr_j obtained by consulting the P_j production records, so that the measurement of the monthly time available (min) of S_2 resulted in a CEr_2 = 19.008,76. Note that the UGr_j is classified in decreasing order and indicates how much resource enters the enterprise for each unit of time that the CCR deals with P_j. This is the measure used by the TA to determine which P_n contributes most to greater profitability for Bianfer Indústria Metalúrgica. It is important to emphasize that the TGr_j refers to values already discounted from the CMt_{ij} and that the use of the PPr_j indicates a revenue of US$ 329,397.95. That said, the Accumulated Production Percentage (APr_j) is the sum of each PPr_j until reaching 100% of the CCR.

4.4 Comparative Analysis of Results

This section presents a comparative analysis of the results obtained by applying AC and TA in defining the TP_{mix} of Bianfer Indústria Metalúrgica. The comparisons were made by simulating three hypothetical scenarios: i) hiring an employee for the production area; ii) increasing sales volume by providing a discount on the price of a product; iii) changing the raw material to reduce the process time at the Capacity Constraint Resource. Table 4 demonstrates the definitions of the TP_{mix} based on AC and TA.

Table 4
Production mix based on Absorption Cost and Throughput Accounting

Production Mix Definition		Absorption Costing		Throughput Accounting	
Product Code (P_j)	Demand Forecast (DF_j)	Selling Price (SP_j)	Revenue Product Total (P_j)	Unit Gain (UG_j)	Total Gain in CRR (TGr_j)
1859	1,479	41.50	61,378.50	38.15	56,423.26
3005	2,824	16.90	47,725.60	11.60	32,744.85
3302	3,163	13.70	43,333.10	10.35	32,735.79
2513	842	54.31	45,729.02	36.58	30,801.04
3358	1,613	21.00	33,873.00	17.65	28,468.81
3003	1,052	37.33	39,271.16	24.91	26,200.70
2511	680	61.29	41,677.20	34.21	23,261.17
3419	1,138	23.59	26,845.42	20.24	23,032.67
3007	2,198	12.97	28,508.06	8.50	18,689.16
3301	2,317	11.40	26,413.80	8.05	18,650.93
3433	575	33.49	19,256.75	30.14	17,330.27
3552	731	18.61	13,603.91	15.26	11,154.77
3518	1,132	12.10	13,697.20	8.75	9,904.55
Tot/Avg.	**19,744**	**22.35**	**441,312.72**	**16.68**	**329,397.95**

Table 4 demonstrates that the total revenue (US$ 441,312.72) calculated using the AC method differs from the total gain obtained through the application of TA (US$ 329,397.95) in defining the TP_{mix}. However, the result is the same for both methods (US$ 215,836.61), that is, the sold products cost (US$ 225,476.11) exceeds the operating expenses (US$

113,561.34). This occurs because the AC prioritizes Pt_j, whereas the TA prioritizes PPr_j. Therefore, the adopted methodology does not impact on the costs of the TP_{mix}. The following hypotheses will be used to evaluate which method provides the best management decision in defining TP_{mix}.

Hypothesis 1 – Hiring 1 employee for the production process (increasing labor costs by US$ 2,000.00 and increasing CCR capacity to 95%), according to Table 5.

Table 5
Recruitment of workforce and increase in Capacity Constraint Resource

Product Code (P_j)	Demand Forecast (DF_j)	Selling Price (SP_j)	Unit Gain (UG_j)	Time in CRR (PTr_j)	Total Time in CRR (TTr_j)	Total Gain in CRR (TGr_j)	Pct. (%) in CRR (PPr_j)	Acc. (%) in CRR (APr_j)
1859	1,479	41.50	38.15	0.967	1,429.75	56,423.26	7.13%	7.13%
2513	**1,173**	**54.31**	**36.58**	**0.900**	**1,055.70**	**42,909.29**	**5.26%**	**12.39%**
3005	2,824	16.90	11.60	0.967	2,729.96	32,744.85	13.61%	25.99%
3302	3,163	13.70	10.35	0.950	3,004.85	32,735.79	14.98%	40.97%
2513	842	54.31	36.58	0.900	757.80	30,801.04	3.78%	44.75%
3358	1,613	21.00	17.65	0.983	1,586.06	28,468.81	7.91%	52.65%
3003	1,052	37.33	24.91	0.933	981.83	26,200.70	4.89%	57.55%
2511	680	61.29	34.21	0.950	646.00	23,261.17	3.22%	60.77%
3419	1,138	23.59	20.24	0.983	1,119.00	23,032.67	5.58%	66.34%
3007	2,198	12.97	8.50	0.967	2,124.81	18,689.16	10.59%	76.94%
3301	2,317	11.40	8.05	0.967	2,239.84	18,650.93	11.16%	88.10%
3433	575	33.49	30.14	0.967	555.85	17,330.27	2.77%	90.87%
3552	731	18.61	15.26	0.983	718.79	11,154.77	3.58%	94.45%
3518	1,132	12.10	8.75	0.983	1,113.10	9,904.55	5.55%	100.00%
Tot/Avg.	**20,917**	**24.14**	**17.80**	**0.959**	**20,063.34**	**372,307.23**	**100.00%**	**100.00%**

The analysis of Table 5, based on the AC, indicates that Hypothesis 1 will generate an increase in IFC. However, the TA indicates an increase in the capacity of S_y with CCR capable of enabling an increase in Pt_n (19,744 to 20,917) and in TGr_n from US$ 329,397.95 (Table 4) to US$ 372,307.23 (Table 5). The hiring of an employee (US$ 2,000.00) is, thus, viable, as it provides for a significant increase in gross (US$ 42,909.29) and net revenue (US$ 40,909.29).

Hypothesis 2 – A customer wishes to purchase 1,000 more units of the P_{2511} (but requests a 10% discount on the SP_{2511}), as shown in Table 6.

Table 6
Increase in sales volume and 10% discount on product price

Product Code (P_j)	Demand Forecast (DF_j)	Selling Price (SP_j)	Unit Gain (UG_j)	Time in CRR (PTr_j)	Total Time in CRR (TTr_j)	Total Gain in CRR (TGr_j)	Pct. (%) in CRR (PPr_j)	Acc. (%) in CRR (APr_j)
1859	1,479	41.50	38.15	0.967	1,429.75	56,423.26	7.52%	7.52%
3005	2,824	16.90	11.60	0.967	2,729.96	32,744.85	14.36%	21.88%
3302	3,163	13.70	10.35	0.950	3,004.85	32,735.79	15.81%	37.69%
2513	842	54.31	36.58	0.900	757.80	30,801.04	3.99%	41.68%
3358	1,613	21.00	17.65	0.983	1,586.06	28,468.81	8.34%	50.02%
2511	**1,000**	**55.16**	**28.38**	**0.950**	**950.00**	**28,381.00**	**5.00%**	**55.02%**
3003	1,052	37.33	24.91	0.933	981.83	26,200.70	5.17%	60.19%
2511	680	61.29	34.21	0.950	646.00	23,261.17	3.40%	63.58%
3419	1,138	23.59	20.24	0.983	1,119.00	23,032.67	5.89%	69.47%
3007	2,198	12.97	8.50	0.967	2,124.81	18,689.16	11.18%	80.65%
3433	575	33.49	30.14	0.967	555.85	17,330.27	2.92%	83.57%
3552	731	18.61	15.26	0.983	718.79	11,154.77	3.78%	87.35%
3301	**1,335**	**11.40**	**8.05**	**0.967**	**1,290.54**	**10,746.22**	**6.79%**	**94.14%**
3518	1,132	12.10	8.75	0.983	1,113.10	9,904.55	5.86%	100.00%
Tot/Avg.	**19,762**	**24.56**	**17.70**	**0.962**	**19,008.34**	**349,874.24**	**100.00%**	**100.00%**

Table 6 demonstrates that for P_{2511} there is a DF_{2511} of 680 whose SP_{2511} is US$ 61.29. The analysis through the AC indicates that UC_{2511} is US$ 54.62 and SP_{2511} with discount is US$ 55.16. In this case, PM_{2511} (US$ 0.54) per unit is highly low and suggests that the discount proposed in Hypothesis 2 should not be applied. The same hypothesis, through the application of TA, evidenced that the discount would provide a TGr_n of US$ 349,874.24, that is, an increase of US$ 20,476.29 compared to the initial projection of US$ 329,397.95 (Table 4). It is possible to see that the increase of 1,000 units of P_{2511} implies a reduction of part of Pt_{3301} (2,317 to 1,335) motivated by the CCR.

Hypothesis 3 – Change of the P_{2511} M_i (speeding up the process in the CCR and changing the PTr_j to 0.910). Table 7 exemplifies the change of the referred M_i with higher CM_i and shorter time in the CCR.

Table 7
Raw material changeover and shorter time in the Capacity Restriction Resource

Product Code (P_j)	Demand Forecast (DF_j)	Selling Price (SP_j)	Unit Gain (UG_j)	Time in CRR (PTr_j)	Total Time in CRR (TTr_j)	Total Gain in CRR (TGr_j)	Pct. (%) in CRR (PPr_j)	Acc. (%) in CRR (APr_j)
1859	1,479	41.50	38.15	0.967	1,429.75	56,423.26	7.52%	7.52%
3005	2,824	16.90	11.60	0.967	2,729.96	32,744.85	14.36%	21.88%
3302	3,163	13.70	10.35	0.950	3,004.85	32,735.79	15.81%	37.69%
2513	842	54.31	36.58	0.900	757.80	30,801.04	3.99%	41.68%
3358	1,613	21.00	17.65	0.983	1,586.06	28,468.81	8.34%	50.02%
3003	1,052	37.33	24.91	0.933	981.83	26,200.70	5.17%	55.19%
3419	1,138	23.59	20.24	0.983	1,119.00	23,032.67	5.89%	61.08%
2511	**680**	**61.29**	**33.65**	**0.910**	**618.80**	**22,882.00**	**3.26%**	**64.33%**
3007	2,198	12.97	8.50	0.967	2,124.81	18,689.16	11.18%	75.51%
3301	2,317	11.40	8.05	0.967	2,239.84	18,650.93	11.78%	87.30%
3433	575	33.49	30.14	0.967	555.85	17,330.27	2.92%	90.22%
3552	731	18.61	15.26	0.983	718.79	11,154.77	3.78%	94.00%
3518	1,132	12.10	8.75	0.983	1,113.10	9,904.55	5.86%	99.86%
2513	**30**	**54.31**	**36.58**	**0.900**	**27.00**	**1,097.42**	**0.14%**	**100.00%**
Tot/Avg.	**19,774**	**22.40**	**16.69**	**0.961**	**19,007.44**	**330,116.20**	**100.00%**	**100.00%**

Table 7 demonstrates that this hypothesis would represent an increase in the TCp_{2511} of 2.07% (from US$ 27.08 to US$ 27.64). An analysis based only on the AC specifically points to an increase in the UC_{2511}. Hence, even increasing UC_{2511}, the enterprise will have a TGr_n of US$ 330,116.20. This value is close to the original situation of US$ 329,397.95 (Table 4). However, this hypothesis favors the fulfillment of a greater number of orders with an increase in Pt_{2513}. Table 8 presents a summary demonstrating the initial application and the results for Hypotheses 1, 2, and 3. Next, Table 9 compares these results with Return on Assets (ROA) based on a value of R$ 1,500,000.00.

Table 8
Demonstration of the initial application and results for Hypotheses 1, 2, and 3.

	Initial Application (Bianfer Scenario)		**Hypothesis 1 (Recruitment)**		**Hypothesis 2 (Vol./Discount)**		**Hypothesis 3 (Change in Mi)**	
Product Code (P_j)	**Demand Forecast (DF_j)**	**Total Gain in CRR (TGr_j)**	**Demand Forecast (DF_j)**	**Total Gain in CRR (TGr_j)**	**Demand Forecast (DF_j)**	**Total Gain in CRR (TGr_j)**	**Demand Forecast (DF_j)**	**Total Gain in CRR (TGr_j)**
1859	1,479	56,423.26	1,479	56,423.26	1,479	56,423.26	1,479	56,423.26
2513	842	30,801.04	**2,015**	**73,710.32**	842	30,801.04	**872**	**31,898.46**
3005	2,824	32,744.85	2,824	32,744.85	2,824	32,744.85	2,824	32,744.85
3302	3,163	32,735.79	3,163	32,735.79	3,163	32,735.79	3,163	32,735.79
2511	680	23,261.17	680	23,261.17	**1,680**	**51,642.17**	**680**	**22,882.00**
3358	1,613	28,468.81	1,613	28,468.81	1,613	28,468.81	1,613	28,468.81
3003	1,052	26,200.70	1,052	26,200.70	1,052	26,200.7	1,052	26,200.70
3419	1,138	23,032.67	1,138	23,032.67	1,138	23,032.67	1,138	23,032.67
3007	2,198	18,689.16	2,198	18,689.16	2,198	18,689.16	2,198	18,689.16
3433	575	17,330.27	575	17,330.27	575	17,330.27	575	17,330.27
3301	2,317	18,650.93	2,317	18,650.93	**1,335**	**10,746.22**	2,317	18,650.93
3552	731	11,154.77	731	11,154.77	731	11,154.77	731	11,154.77
3518	1,132	9,904.548	1,132	9,904.548	1,132	9,904.55	1,132	9,904.55
Tot/Avg.	**19,744**	**329,397.95**	**20,917**	**372,307.23**	**19,762**	**349,874.24**	**19,774**	**330,116.20**

Table 9
Comparison of return on assets between the initial application and Hypotheses 1, 2, and 3.

Evaluation Metrics Results Assessment	**Initial Application (Bianfer Scenario)**	**Hypothesis 1 (Recruitment)**	**Hypothesis 2 (Vol./Discount)**	**Hypothesis 3 (Change in Mi)**
Demand Forecast (DFj)	19,744	20,917	19,762	19,774
Total Gain in CRR (TGrj)	329,397.95	372,307.23	349,874.24	330,116.20
Total Operating Expenses	113,561.34	115,561.34	113,561.34	113,561.34
Result (Application of TA)	**215,836.61**	**256,745.89**	**236,312.90**	**216,554.86**
Return on Assets (Pct. ROA)	**14.39%**	**17.12%**	**15.75%**	**14.44%**

Table 9 demonstrates that ROA is another important metric in the decision-making process at Bianfer Indústria Metalúrgica. The initial application of TA (Table 9) shows a result of US$ 215,836.61 and an ROA of 14.39%. However, Hypothesis 1, despite increasing expenditures (from US$ 113,561.34 to US$ 115,561.34) for hiring one production employee, raises the result (US$ 256,745.89) and the ROA to 17.12%. Hypothesis 1 analyzed only with management data from the AC method would likely not be approved by Bianfer Indústria Metalúrgica. Therefore, managerial decisions may differ if labor costs and their impact on profitability are analyzed using the TA. The other hypotheses also provide satisfactory increases in results and in ROA to 15.75% (Hypothesis 2) and 14.44% (Hypothesis 3). However, defining the TP_{mix} solely based on AC

may prompt managers to make suboptimal interpretations and decisions for Bianfer Indústria Metalúrgica. We further emphasize that neither AC nor TA impacts the *TCTP* reduction within a specified TP_{mix}. The comparative analyses presented by this study merely suggest that TA is the most appropriate method for the definition of the TP_{mix} and the maximization of product yield at Bianfer Indústria Metalúrgica. Another point of attention is that the monthly accounting closing frequency and the reliance on contribution margin also hinder rapid decision-making regarding the TP_{mix}. Furthermore, the implementation of complex systems may be costly and inappropriate for the structures and resources of MSEs. The methodology proposed by TA better addresses these practical issues by providing data and information more swiftly and precisely using Microsoft Office Excel. This agility can also better support the sales team in negotiations and enhance the economic and financial return for Bianfer Indústria Metalúrgica. The limited understanding of TA applications may elicit uncertainty and skepticism regarding their benefits and disadvantages compared to the approaches proposed by TCA. This paper demonstrates that different methods can be utilized in conjunction and adapted without significant difficulty to the specificities inherent in MSEs.

5. Final Considerations

This study presented a case study that applied Throughput Accounting (TA) to support decision-making regarding the production mix of a small enterprise named Bianfer Indústria Metalúrgica, located in Jaú, São Paulo (SP), Brazil. The metallurgical enterprise produces parts and components for the agricultural sector and operates in a competitive market characterized by limited differentiation among production sectors in Brazil. The decision-making processes in the sales and production areas are based on the managers' experience combined with Absorption Costing (AC). The proposed approach employed Microsoft Office Excel 365 to simulate three scenarios with distinct hypotheses for production mix decisions and compared the outcomes obtained by AC and TA regarding Return on Assets (ROA). The analysis demonstrated that TA is a more agile and precise management tool for defining the production mix, yielding superior financial results compared to AC. The application of TA does not require substantial investments or complex implementation and can support the execution of the sales policy while enhancing the economic and financial performance of Bianfer Indústria Metalúrgica. This tool offered greater visibility into restrictive resources and fostered the acquisition of new knowledge and changes in management culture previously overlooked by Bianfer Indústria Metalúrgica. We emphasized that the analyzed methods can be jointly utilized and adapted with relative ease to various segments and specificities of Micro and Small Enterprises (MSEs). Evidently, there is a lack of knowledge among managers and a significant gap concerning the application of TA to MSEs. Therefore, this study addressed a critical practical gap between theory and practice, aiming to guide students, professionals, and researchers in the application of TA in MSEs. The main contribution of this study resides in the empirical evidence that TA is an effective management tool for MSEs. The implementation of TA through a simple Microsoft Office Excel model can substantially enhance production mix decision-making in MSEs.

However, this case study has limitations that should be considered in future applications of TA in MSEs. A significant limitation resides in the short-term focus, which, by neglecting future strategies and investment needs, can compromise the competitiveness of Bianfer Indústria Metalúrgica. Furthermore, this study did not yet consider external variables (economic fluctuations, demand variations, etc.) necessary for the rapid market adaptability of Bianfer Indústria Metalúrgica. The methodology of treating fixed costs as operating expenses may generate a mistaken simplification and negatively affect the financial results of MSEs. The emphasis given solely to the cost of direct materials also does not offer possibilities for reducing the total cost of production in MSEs. Decision-making processes for equipment acquisition or capacity expansion still need to be carried out using traditional managerial accounting methods and Traditional Cost Accounting (TCA). The simulations based on three hypothetical scenarios, performed only in one specific area of the company, do not accurately reflect all possibilities related to the real operational dynamics at Bianfer Indústria Metalúrgica. Attention should be paid to the risk of TA's inability to adequately capture or underestimate the operational complexities of dynamic environments with multiple bottlenecks or flexible processes in MSEs. Another important limitation that may restrict the proposed model lies in the constraints related to Microsoft Office Excel. Although accessible and low-cost, this tool restricts its capacity to manage the complexity of optimization models developed for MSEs. There is no doubt that the use of advanced tools and hybrid methods that include more robust algorithms and technologies such as big data and artificial intelligence could offer greater accuracy for TA. However, the implementation of these advancements is often difficult or unfeasible due to the limited structures and resources evident in most MSEs. Future studies may explore: i) the role of big data and artificial intelligence in the application of TA; ii) the application of heuristics (exact and constructive) and metaheuristics (to improve solutions) adapted to TA; iii) factors such as organizational culture, enterprise size, and market structure that influence the application of TA; and iv) environments with multiple constraints in the production process and the associated challenges for the effective implementation of TA.

Acknowledgements

This study's findings are derived from José Renato Luchini's Master's Dissertation.

Financing

This research was funded by Research Project Grants Nº. 404819/2023-0 and 402671/2025-2 from the National Council for Scientific and Technological Development – CNPq, and by Research Project Grant Nº. 2700441 from the National Foundation for the Development of Private Higher Education – FUNADESP.

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