Research Article

Aibi research, management and engineering journal. Volume 13, Number 3, Pag 1-09, September - December 2025, ISSN 2346-030X

Application and impact assessment of an intelligent time management system in small and medium sized enterprises

Alberto Aguilera[1], Daniel Sierra[2], Efrain Solares[3], Jorge Alfonso Lara-Pérez[4], Juan Antonio Álvarez-Gaona[5], Juan Antonio Granados-Montelongo[6]

[1,2]*Universidad Autónoma de Chihuahua, Chihuahua - México*

[3]*Universidad Autónoma de Coahuila, Torreón - México*

[4]*Universidad Autónoma de Ciudad Juárez, Ciudad Juárez - México*

[5]*Universidad Autónoma de Coahuila, Saltillo - México*

[6]*Universidad Autónoma Agraria Antonio Narro, Saltillo - México*

Received: february 25, 2025.
Accepted: july 19, 2025.
Publicado: september 01, 2025.

Abstract— This study explores the application and effectiveness of an advanced decision support methodology aimed at improving time management and managerial efficiency within Small and Medium Enterprises (SMEs). By integrating value function theory with differential evolution, the research presents a robust framework tailored to the dynamic nature of SMEs. The methodology is assessed through a comprehensive pre- and post-implementation analysis, focusing on key performance indicators such as general sales, margin on sales, and the accounts receivable cycle. Findings from multiple case studies reveal notable enhancements in managerial efficiency and overall business performance, particularly under conditions of uncertainty and complex decision-making. The system's adaptability and alignment with local business practices further highlight its potential for broader application in emerging markets. This research contributes novel insights into organizational management and decision support systems by addressing cultural and economic variables often overlooked in conventional approaches.

Keywords: decision support systems, optimization; computational techniques; time management.

*Corresponding author: efrain.solares@uadec.edu.mx (Efrain Solares).

Peer reviewing is a responsability of the Universidad de Santander.
How to cite this article: A. Aguilera, D. Sierra, E. Solares, J. A. Lara-Pérez, J. A. Álvarez-Gaona and J. A. Granados-Montelongo, “Application and impact assessment of an intelligent time management system in small and medium sized enterprises”, Aibi research, management and engineering journal, vol. 13, no. 3, pp. 01-09 2025, doi: 10.15649/2346030X.5669

I. INTRODUCTION

In today's rapidly evolving business landscape, the effective management of time at the managerial level has become a critical determinant of organizational success. This is particularly pronounced in the dynamic business environments within small and medium-sized enterprises (SMEs) that face unique challenges demanding efficient resource allocation and strategic decision-making.

The capacity to optimize time, a non-renewable resource, can significantly influence an organization's ability to innovate, respond to competitive pressures, and achieve sustainable growth. It is within this context that our study describes the application of a sophisticated decision support system designed to enhance managerial efficiency through advanced time management strategies.

The theoretical foundation of our approach is built upon the integration of value function theory [1] and differential evolution [2]—a combination that tailors decision-making processes to the specific needs and preferences of managers. Value function theory allows for the quantification of managerial preferences, converting subjective assessments of activity importance into measurable criteria [3]. This is crucial in environments where managerial decisions directly impact operational efficiency and strategic outcomes. Differential evolution, a type of evolutionary algorithm, further refines this process by offering a robust optimization framework capable of navigating complex decision landscapes where multiple activities and conflicting priorities must be balanced [4], [5].

This methodology not only addresses the theoretical requirements for effective time management but also emphasizes the practical application within the specific socio-economic context of Mexican SMEs. The country's vibrant industrial and commercial sectors make it a compelling case study for examining the real-world applicability of advanced management theories. By focusing on this locale, the study also responds to a broader academic and practical need for research that situates decision support systems within culturally and economically diverse environments.

Our research goes beyond theoretical development to include a practical application phase where the proposed system is implemented across a range of SMEs. This implementation phase is critical for assessing the adaptability of the system to different organizational contexts and managerial styles. It involves a detailed pre- and post-implementation analysis that measures the system's impact on managerial efficiency and organizational performance. Key performance indicators such as general sales, margin on sales and accounts receivable cycle, are identified and tracked to provide a quantitative basis for evaluating improvements brought about by the system.

Furthermore, this study contributes to the existing literature on managerial efficiency and decision support systems by demonstrating how integrated approaches can be tailored to fit the cultural and economic specifics of a given region. Most literature in this field tends to emphasize universal solutions that may not take into account local business practices or economic conditions. By contrast, our approach recognizes the importance of contextual adaptability, offering insights into how systems can be designed to be both globally informed and locally applicable [6], [7].

In addition to its practical contributions, the study addresses several theoretical gaps. Firstly, it extends the application of differential evolution in managerial decision-making, an area that has seen limited exploration compared to its use in engineering and technical fields. Secondly, it provides a novel application of value function theory in a real-world business setting, offering a new perspective on how this theory can be operationalized to enhance decision-making processes. The integration of these two sophisticated methodologies presents a significant advancement in the field of management science, promising to offer valuable insights into both the theory and practice of time management [8], [9].

The expected outcomes of this research are manifold. From the academic perspective, it provides a rigorous methodological framework that can be further explored and adapted. For practitioners, particularly those in similar emerging market contexts, the findings offer actionable strategies that can be employed to enhance managerial effectiveness and organizational outcomes. Moreover, the study's focus on the case study enriches the understanding of how business theories and practices can be effectively implemented in emerging markets, contributing to the broader discourse on global management practices.

The paper is structured as follows. Section II describes the materials and methods required by the methodology in order to achieve the expected goals; this section also explains the series of steps followed to apply the methodology in the case study. Section II provides the results of the application. Finally, Section II discusses the results and concludes the paper.

II. MATERIALS AND METHODS

This section describes a comprehensive framework for modeling and optimizing managerial time allocation, integrating value functions, interval numbers, and differential evolution. The methodology is specially tailored to capture nuanced preferences of managers and inherent uncertainties in determining optimal time allocations for various managerial activities.

a. Overview of the Methodological Framework.

The methodological framework of this study is grounded in the integration of value functions, interval analysis, and differential evolution, which together create a robust approach for optimizing managerial time allocation. This framework is tailored to meet the unique demands of the dynamic business environment in SMEs, reflecting both the complexity of managerial roles and the varying priorities that characterize the regional market.

The optimization of time allocation across various managerial activities is achieved through differential evolution, a type of evolutionary algorithm renowned for its effectiveness in solving complex optimization problems with continuous variables. This component of the framework adjusts the allocation strategies based on evolving conditions and feedback, ensuring that the solutions remain optimal and relevant over time.

To address uncertainties inherent in managerial decision-making—such as fluctuating market conditions or incomplete information—our methodology incorporates interval analysis.

Together, these elements form a comprehensive methodological framework that not only enhances the decision-making capabilities of managers but also adapts to the intrinsic complexities and uncertainties of managing in a culturally and economically diverse environment like those in SMEs. By systematically aligning managerial activities with organizational goals and local market dynamics, the framework supports sustainable business growth and improved operational efficiency.

b. Differential Evolution.

Differential Evolution (DE) [10] is a robust optimization algorithm integral to our methodological framework, specifically chosen for its efficacy in handling complex optimization problems involving continuous decision variables. This subsection outlines the operational specifics of DE, explaining its role in optimizing managerial time allocation within our proposed system.

Differential Evolution operates on the principles of natural selection and genetics, making it an excellent tool for exploring potential solutions in complex optimization landscapes [11]. It starts with a randomly generated population of potential solutions, each represented as a multi-dimensional vector corresponding to different decision variables in the managerial time allocation problem.

The following are the key parameters of DE [12].

- Population Size (Psize). The total number of potential solutions considered simultaneously. A larger population size allows for a more thorough exploration of the solution space but requires more computational resources.
- Crossover Probability (CR). A parameter that determines the likelihood of different elements (genes) from two solution vectors (parents) combining to form a new vector (offspring). This parameter influences the diversity of solutions generated.
- Differential Weight (F). This factor scales the difference between two randomly selected vectors from the population before adding it to a third vector. It affects the rate at which the population evolves and can help the algorithm escape local optima.

While the following are the operational mechanics of the algorithm.

1. Initialization: Generate an initial population of vectors randomly distributed throughout the potential solution space.
2. Mutation: For each vector (target), a mutant vector is generated by adding the weighted difference between two randomly selected population vectors to a third randomly selected vector.
3. Crossover: Elements from the mutant vector and the target vector are mixed to create a trial vector. The crossover probability determines whether each element of the target vector is replaced by the corresponding element from the mutant vector.
4. Selection: If the trial vector yields a better or equal fitness score compared to the target vector (according to a predefined fitness function), it replaces the target in the population.

Fitness Function: The effectiveness of each vector (solution) is determined by a fitness function, which evaluates how well a particular time allocation meets the predefined criteria of efficiency and effectiveness in managerial tasks. This function is crucial as it guides the evolutionary process toward increasingly effective solutions.

Iterative Improvement: The process of mutation, crossover, and selection is repeated over multiple generations until a stopping criterion is met, which could be a set number of generations, a time limit, or a satisfactory fitness level. This iterative process ensures that the solutions evolve towards the optimal configuration, adapting to the complex and dynamic priorities characteristic of managerial responsibilities.

By leveraging Differential Evolution, our methodology not only optimizes the allocation of managerial time but also adapts to the intrinsic complexities and uncertainties of managing in a culturally and economically diverse environment like those in SMEs. This approach ensures that managerial activities are aligned with strategic business objectives, thereby enhancing overall organizational performance.

c. Functional approach.

The functional approach, as applied within our methodological framework, serves as a critical component in assessing and prioritizing managerial activities based on their perceived importance and impact on organizational goals [13]. This subsection delves into how the functional approach is operationalized to facilitate effective decision-making in the context of managerial time allocation.

The functional approach in decision-making, often referred to as axiology in philosophical terms, involves evaluating and determining the worth of options within a decision-making process. In managerial contexts, it translates subjective preferences and priorities into quantifiable metrics that can guide the allocation of resources, particularly time. This theory is especially pertinent for ensuring that managerial decisions align with strategic objectives and contribute optimally to organizational outcomes.

Central to our approach is the construction of value functions that quantitatively represent the utility of devoting time to various managerial tasks. These functions are derived from empirical data gathered through surveys and interviews with managers, which assess their preferences and the perceived impact of each activity.

By applying value functions, we translate subjective evaluations into a ranked or scaled format that facilitates clear comparisons and prioritizations among different activities. This process ensures that managers can make informed decisions about where to allocate their limited time to maximize organizational benefits.

Key to effective value function development is the elicitation of managerial preferences, which involves understanding the relative importance managers place on different activities. Techniques such as pairwise comparison and ranking exercises are used to gather this data.

The value functions are regularly calibrated based on ongoing feedback and changes in organizational priorities or external conditions, ensuring they remain relevant and accurately reflect current managerial views and business needs.

The value assessments are integrated into the differential evolution algorithm, serving as part of the fitness function that evaluates the effectiveness of different time allocation strategies. As the optimization process unfolds, the value functions can be adjusted to respond to new insights or shifts in strategic direction, allowing the decision support system to adapt dynamically to changing organizational landscapes.

d. Interval Theory.

Interval Theory plays a vital role in our methodological framework, enhancing the decision-making process by effectively managing the uncertainties inherent in managerial time allocation [14], [15], [16]. This subsection details the application of Interval Theory to quantify and handle these uncertainties, ensuring robust and adaptable decision-making. Interval Theory involves the use of interval numbers to represent quantities whose exact values are uncertain but bounded within known limits. This mathematical approach allows for the modeling of uncertainties in a way that traditional point estimates do not, providing a range of possible outcomes that reflect the real-world ambiguity faced by managers.

In the context of managerial time allocation, Interval Theory is used to represent the uncertain impact of various activities on organizational outcomes. For instance, the exact benefit of spending an additional hour on strategic planning may not be precisely known; however, it can be bounded within a range that reflects expert opinion and historical data. Each managerial activity is associated with interval numbers that encapsulate the possible values of metrics such as impact, effort required, and potential return. These intervals are derived from both quantitative data and qualitative judgments provided by managers.

The interval numbers are integrated into the decision-making framework, where they are used to calculate the robustness of different time allocation strategies. This integration allows the system to evaluate which strategies provide the best outcomes under varying assumptions and scenarios. As new information becomes available or as market conditions change, the interval numbers can be updated to reflect these changes, allowing the decision support system to adapt dynamically to new circumstances.

Basic operations such as addition, subtraction, multiplication, and division are performed using interval arithmetic rules. This ensures that the results of calculations involving interval numbers remain valid and bounded, despite the inherent uncertainties. Consider A=[a^-,a^+] and B=[b^-,b^+] as two interval numbers. The arithmetic operations involving these numbers are defined as follows.

$$\boldsymbol{A} + \boldsymbol{B} = [a^- + b^-, a^+ + b^+],$$
$$\boldsymbol{A} - \boldsymbol{B} = [a^- - b^+, a^+ - b^-],$$
$$\boldsymbol{A} \times \boldsymbol{B} = [\min\{a^-b^-, a^-b^+, a^+b^-, a^+b^+\}, \max\{a^-b^-, a^-b^+, a^+b^-, a^+b^+\}].$$

Interval optimization techniques are employed to determine the best time allocation strategies. These techniques consider the range of possible outcomes and seek to find solutions that are optimal across the broadest range of scenarios, enhancing decision robustness.

The use of interval numbers adds a layer of complexity to the decision-making process. To manage this complexity, sophisticated computational tools and algorithms are employed, ensuring that the calculations remain tractable and the results interpretable. While interval numbers provide a more accurate reflection of uncertainty, they may reduce the precision of specific predictions. This trade-off is managed by carefully selecting the width of the intervals based on the level of uncertainty and the tolerance for risk in decision-making.

By incorporating Interval Theory into our framework, we equip managers with the tools to make informed decisions despite the inherent uncertainties of their environment. This approach not only enhances the adaptability and resilience of managerial strategies but also aligns with the dynamic and uncertain nature of business operations in SMEs.

e. Application and Effectiveness Assessment in Small and Medium Enterprises.

This subsection explores how our comprehensive time management approach is adapted and applied within Small and Medium Enterprises and outlines the methodology used to assess its effectiveness. Given the unique challenges and resource constraints typical of SMEs, the adaptability and precision of our approach are vital for enhancing decision-making and operational efficiency in these environments.

Application in SMEs

The decision support system is customized to fit the specific operational needs and strategic goals of SMEs by calibrating the value functions and interval numbers to align with the scale and scope of activities typical in smaller business settings.

Managers in SMEs receive extensive training on how to effectively utilize the system, including interpreting recommendations and adjusting their time allocation strategies accordingly. This training ensures that the system is fully leveraged. Furthermore, the system is integrated with existing managerial processes and tools within SMEs to enhance utility without disrupting established practices.

Effectiveness Assessment

Effectiveness is rigorously assessed by comparing key performance indicators (KPIs) before and after the implementation of the system. The selected KPIs include net sales, margin on sales, the accounts receivable cycle, customers decrease, gross profit, purchase frequency, sales per customer, costs of sale, operating costs, and utility operation, which provide insights into productivity, profitability, and financial efficiency. These metrics are tracked to quantify improvements in revenue growth, cost management, and cash flow—crucial factors for SMEs' sustainability and growth. Each of these KPIs is defined in Table 1. However, it is important to highlight that not all the SMEs accepted to provide information about all these KPIs [17], [18], [19], [20]; therefore, some of them were assess only on a subset of the indicators.

Table 1: Definition of each KPI used by the SMEs.

Metric	Definition
Net Sales	The total revenue from sales after deducting returns, allowances, and discounts.
Margin on Sales	The percentage of sales revenue that turns into gross profit; calculated as (Gross Profit / Net Sales) × 100.
Accounts Receivable Cycle	The average number of days it takes a company to collect payments after a sale has been made.
Customers Decrease	A reduction in the number of customers over a specific period, indicating potential issues in customer retention or market reach.
Gross Profit	The profit a company makes after deducting the costs associated with making and selling its products (i.e., costs of goods sold).
Purchase Frequency	The average number of times a customer makes a purchase within a set period.
Sales per Customer	The average sales revenue generated per customer, which helps in understanding customer value.
Costs of Sale	The direct costs attributable to the production of the goods sold by a company.
Operating Costs	The expenses related to the operation of a business, excluding the cost of goods sold.
Utility Operation	The efficiency and effectiveness with which a company uses its resources to produce profitable operations.
Metric	Definition

Source: own elaboration.

A baseline assessment of these KPIs is conducted prior to the system's implementation to establish a reference point. Subsequent assessments post-implementation allow for direct comparison to evaluate the tangible impact of the system on managerial efficiency and organizational performance.

However, since natural tendencies in the particular SME can interfere in the assessment procedure, we ask the SME to provide the goal for the month in the respective KPI and compare the KPI's actual assessment to that goal; we continue this assessment each month and what we determine to be the effectiveness of the comprehensive approach is the changes in the discrepancies between goals and actual assessments of the KPI.

The Regular feedback from managers is also solicited to assess the model's user-friendliness, relevance, and impact, informing iterative improvements to the system and its application in the SME context.

Through this methodical application and comprehensive evaluation, the study aims to provide robust evidence of the model's effectiveness and practical benefits. This approach contributes significantly to the understanding of how SMEs can leverage sophisticated decision support systems to achieve greater efficiency and strategic advantage in competitive markets.

III. RESULTS

As stated before, the assessment procedure, conducted from June to December, focused on several KPIs, capturing the variance between actual outcomes and target goals. The current section provides the results of assessing each of SME on a subset of these indicators according to the specific requirements of each SME.

a. Advised time allocation.

The model's outcomes highlight a pragmatic and adaptable approach embedded within our optimization process. It recognizes the fluid nature of managerial duties, where the prioritization of certain activities may need to shift in response to changing organizational requirements, external influences, or adjustments in strategic direction. By offering recommendations that fall within specific ranges, the model grants managers the flexibility to adjust their time allocations to meet immediate demands while still aligning with their overarching strategic aims.

Thus, the recommendations are not rigid mandates but rather flexible guidelines designed to facilitate informed decision-making. This equilibrium between adaptability and reliability in the recommendations ensures that managers can make well-judged decisions that cater to both immediate operational demands and broader strategic objectives, ultimately enhancing the effectiveness and efficiency of managerial tasks, as shown in Table 2.

Table 2: The system provides strategic recommendations that maximize the value of activities from the perspective of managers (data taken from [21]).

Activity	Best Time Recommended (%)	
Vendor Relationship Management - VRM	8.52	22.31
Sales and Marketing Oversight - SMO	6.97	7.83
Organizational Strategy Formulation - OSF	10.56	12.70
Operational Administration - OA	5.22	9.91
Stock Control - SC	2.46	7.03
Monetary Resources Management - MRM	4.80	10.77
Tactical Leadership - TL	4.42	7.59
Excellence and Client Satisfaction Assurance - ECSA	16.02	18.55
Talent and Workforce Management - TWM	20.92	23.67

Source: own elaboration.

Recall that the recommendations are expressed as interval numbers in order to provide the manager with flexibility.

b. SME 1: distributor of frozen foods.

Established in 2013, this company specializes in the wholesale and retail distribution of frozen foods, including chicken, potatoes, and seafood. The company has a workforce of 20, including roles in management, administration, operations, warehouse, and sales. The senior business management requested the assessment of this enterprise on the following KPIs: Net Sales, Operating Costs, Costs Utility Operation, Accounts Receivable.

Table 3 shows the original scores on the selected KPIs for this enterprise (before the application of the approach). All the money values are expressed on Mexican pesos.

Table 3: Original KPIs scores for SME1 (June, 2023).

KPI	Target	Real	Discrepancy
Net Sales	$3,766,183.49	$4,105,913.84	-0.56%
Operating Costs	$442,959.26	$483,170.78	1.70%
Costs Utility Operation	$221,565.29	$241,615.46	6.20%
Accounts Receivable	$600,000.00	$584,028.80	-2.66%

Source: own elaboration.

After applying the methodology to this enterprise's manager, she started following the instructions provided in Table 2. Evidently, the manager did not start following the recommendations exactly from the beginning, but she was adapting her activities along the experimentation period, as shown in Table 4. Note that in Table 2 the real time allocated by the manager to each activity is provided as an interval number; this is to facilitate the way in which she estimates the time allocated.

Table 4: Times allocated by SME1's manager during the experimentation phase and the deviations regarding the recommended allocation in Table 2.

	July		August		September	
	Real	Deviation	Real	Deviation	Real	Deviation
VRM	[2,4]	[-20.31,-4.52]	[3,6]	[-19.31,-2.52]	[4,12]	[-18.31,3.48]
SMO	[55,84]	[47.17,77.03]	[23,41]	[15.17,34.03]	[15,36]	[7.17,29.03]
OSF	[4,7]	[-8.7,-3.56]	[7,11]	[-5.7,0.44]	[12,20]	[-0.7,9.44]
OA	[0,3]	[-9.91,-2.22]	[10,24]	[0.09,18.78]	[9,15]	[-0.91,9.78]
SC	[0,0]	[-7.03,-2.46]	[0,17]	[-7.03,14.54]	[7,13]	[-0.03,10.54]
MRM	[0,5]	[-10.77,0.2]	[3,7]	[-7.77,2.2]	[3,6]	[-7.77,1.2]
TL	[0,7]	[-7.59,2.58]	[5,15]	[-2.59,10.58]	[1,16]	[-6.59,11.58]
ECSA	[0,7]	[-18.55,-9.02]	[0,8]	[-18.55,-8.02]	[3,10]	[-15.55,-6.02]
TWM	[0,21]	[-23.67,0.08]	[4,41]	[-19.67,20.08]	[4,11]	[-19.67,-9.92]
	October		November		December	
	Real	Deviation	Real	Deviation	Real	Deviation
VRM	[5,8]	[-17.31,-0.52]	[8,9]	[-14.31,0.48]	[4,7]	[-18.31,-1.52]
SMO	[15,31]	[7.17,24.03]	[21,29]	[13.17,22.03]	[21,31]	[13.17,24.03]
OSF	[5,13]	[-7.7,2.44]	[4,11]	[-8.7,0.44]	[6,14]	[-6.7,3.44]
OA	[7,25]	[-2.91,19.78]	[8,15]	[-1.91,9.78]	[16,27]	[6.09,21.78]
SC	[8,12]	[0.97,9.54]	[5,11]	[-2.03,8.54]	[1,8]	[-6.03,5.54]
MRM	[4,6]	[-6.77,1.2]	[5,10]	[-5.77,5.2]	[2,6]	[-8.77,1.2]
TL	[11,17]	[3.41,12.58]	[11,17]	[3.41,12.58]	[7,19]	[-0.59,14.58]
ECSA	[5,9]	[-13.55,-7.02]	[6,13]	[-12.55,-3.02]	[7,11]	[-11.55,-5.02]
TWM	[5,9]	[-18.67,-11.92]	[6,11]	[-17.67,-9.92]	[2,12]	[-21.67,-8.92]

Source: own elaboration.

It can be appreciated from Table 4 that the manager struggled to adjust her activities to the recommendations of the methodology. To make this analysis clearer, we used the middle point of the interval numbers and indicators (cf., [14]), as shown in Table 5.

Table 5: Times allocated and deviations calculated by interval numbers' middle points for SME1.

	July	August	September	October	November	December
VRM	-12.415	-10.915	-7.415	-8.915	-6.915	-9.915
SMO	62.1	24.6	18.1	15.6	17.6	18.6
OSF	-6.13	-2.63	4.37	-2.63	-4.13	-1.63
OA	-6.065	9.435	4.435	8.435	3.935	13.935
SC	-4.745	3.755	5.255	5.255	3.255	-0.245
MRM	-5.285	-2.785	-3.285	-2.785	-0.285	-3.785
TL	-2.505	3.995	2.495	7.995	7.995	6.995
ECSA	-13.785	-13.285	-10.785	-10.285	-7.785	-8.285
TWM	-11.795	0.25	-14.795	-15.295	-13.78	-15.295

Source: own elaboration.

The tendency to follow recommendations more closely can be seen in Table 5.

Finally, Table 6 shows the actual impact that following the recommendations generated on the KPIs of SME1.

Table 6: Impact of the methodology on the SME1'S KPIs.

KPI	June (original)	July	August	September	October	November	December
Net Sales	-0.56%	-4.47%	-1.00%	-0.73%	-3.28%	0.98%	-5.72%
Operating Costs	1.70%	21.10%	31.30%	52.60%	48.00%	30.30%	66.70%
Costs Utility Operation	6.20%	33.60%	-45.60%	-92.80%	-40.40%	-77.20%	-37.80%
Accounts Receivable	-2.66%	-15.5%	26.23%	-19.54%	-18.59%	-3.5%	-0.3%

Source: own elaboration.

c. *SME2: Supplier of MRO materials.*

With over 20 years of experience, SME2 serves the manufacturing industry as a supplier of MRO (maintenance, repair, and operations) materials, boasting a client portfolio of tens of customers. They provide a wide range of materials and have adapted their services to meet specific client needs. The company operates with a modern office setup and a fleet of six vehicles to ensure quick delivery services.

Their staff includes 18 employees spread across general management, administration, purchasing, and delivery. The senior business management requested the assessment of this enterprise on the following KPIs: Net Sales, Margin on Sales and Accounts Receivable Cycle.

Table 7 shows the original scores on the selected KPIs for this enterprise (before the application of the approach).

Table 7: Original KPIs scores for SME2 (June, 2023).

KPI	Target	Real	Discrepancy
Net Sales	$5,000,000.00	$4,072,154.82	-19%
Margin on Sales	30.00%	24.00%	-20%
Accounts Receivable Cycle	60	78.48	31%

Source: own elaboration.

Note that Accounts Receivable Cycle is to be minimized, that is, the lower the better. After implementing the methodology, the enterprise's manager also progressively adapted his activities to align with the recommendations, showing the adjustment detailed in Table 8.

Table 8: Times allocated by SME2's manager during the experimentation phase and the deviations regarding the recommended allocation in Table 2.

	July		August		September	
	Real	**Deviation**	**Real**	**Deviation**	**Real**	**Deviation**
VRM	[0,5.71]	[-22.3,-2.81]	[0,11.43]	[-22.31,2.91]	[0.09,0.1]	[-22.2,-8.38]
SMO	[0,5.71]	[-7.83,-1.26]	[0,14.29]	[-7.83,7.32]	[0.03,0.1]	[-7.8,-6.86]
OSF	[0,4.29]	[-12.7,-6.27]	[0,8.57]	[-12.7,-1.99]	[0.03,0.1]	[-12.7,-10.5]
OA	[57.14,76.4]	[47.23,71.21]	[20,60]	[10.09,54.78]	[0.14,0.37]	[-9.77,-4.85]
SC	[5.71,17.14]	[-1.32,14.68]	[2.86,28.57]	[-4.17,26.11]	[0.06,0.14]	[-6.97,-2.32]
MRM	[0,9.52]	[-10.77,4.72]	[5.71,14.29]	[-5.06,9.49]	[0.06,0.09]	[-10.71,-4.7]
TL	[0,11.43]	[-7.59,7.01]	[0,14.29]	[-7.59,9.87]	[0,0.06]	[-7.59,-4.36]
ECSA	[0,4.76]	[-18.55,-11.2]	[0,11.43]	[-18.55,-4.59]	[0,0.14]	[-18.5,-15.8]
TWM	[0,12.14]	[-23.67,-8.78]	[2.86,20]	[-20.81,-0.92]	[0.17,0.26]	[-23.5,-20.6]
	October		**November**		**December**	
	Real	**Deviation**	**Real**	**Deviation**	**Real**	**Deviation**
VRM	[0.03,0.11]	[-22.28,-8.4]	[0.03,0.14]	[-22.28,-8.3]	[0.06,0.11]	[-22.25,-8.4]
SMO	[0.06,0.09]	[-7.77,-6.88]	[0.06,0.2]	[-7.77,-6.77]	[0,0.11]	[-7.83,-6.86]
OSF	[0.03,0.09]	[-12.67,-10]	[0,0.11]	[-12.7,-10.4]	[0,0.11]	[-12.7,-10.5]
OA	[0.23,0.29]	[-9.68,-4.93]	[0.14,0.27]	[-9.77,-4.95]	[0.23,0.32]	[-9.68,-4.9]
SC	[0.09,0.11]	[-6.94,-2.35]	[0.11,0.14]	[-6.92,-2.32]	[0.06,0.14]	[-6.97,-2.32]
MRM	[0,0.11]	[-10.77,-4.7]	[0.05,0.19]	[-10.72,-4.6]	[0.03,0.14]	[-10.74,-4.6]
TL	[0.03,0.11]	[-7.56,-4.31]	[0,0.1]	[-7.59,-4.32]	[0,0.09]	[-7.59,-4.33]
ECSA	[0.06,0.11]	[-18.5,-15.9]	[0,0.09]	[-18.5,-15.9]	[0,0.06]	[-18.5,-15.9]
TWM	[0.2,0.23]	[-23.4,-20.7]	[0.11,0.29]	[-23.6,-20.6]	[0.17,0.29]	[-23.5,-20.6]

Source: own elaboration.

The time allocations by the manager are provided in Table 12.

Table 12: Times allocated by SME3's manager during the experimentation phase and the deviations regarding the recommended allocation in Table 2.

	July		August		September	
	Real	**Deviation**	**Real**	**Deviation**	**Real**	**Deviation**
VRM	[1.9,9.5]	[-20.5,1]	[2.9,1]	[-19.4,4.4]	[5.6,1.8]	[-16.8,6.3]
SMO	[0,4.8]	[-7.8,-2.2]	[3.3,19.8]	[-4.5,12.8]	[11.1,14.8]	[3.3,7.8]
OSF	[0,3.7]	[-12.7,-6.9]	[1.9,8.1]	[-10.9,-2.5]	[1.9,14.8]	[-10.9,4.3]
OA	[27,44.4]	[17.1,39.2]	[12.2,42.8]	[2.3,37.6]	[14.8,22.2]	[4.9,17]
SC	[7.4,15.9]	[0.4,13.4]	[5.6,20.4]	[-1.5,17.9]	[7.4,14.8]	[0.4,12.4]
MRM	[18.5,26.9]	[7.8,22.1]	[10.7,22.2]	[-0.1,17.4]	[16.7,22.2]	[5.9,17.4]
TL	[3.7,7.4]	[-3.9,3]	[1.9,18.8]	[-5.7,14.3]	[1.9,7.4]	[-5.7,3]
ECSA	[7.4,16.7]	[-11.1,0.7]	[0,9.3]	[-18.6,-6.8]	[5.6,9.3]	[-13,-6.8]
TWM	[3.7,14.8]	[-20,-6.1]	[8.5,14.6]	[-15.2,-6.4]	[9.3,13]	[-14.4,-8]
	October		**November**		**December**	
	Real	**Deviation**	**Real**	**Deviation**	**Real**	**Deviation**
VRM	[1.9,11.1]	[-20.5,2.6]	[7,9]	[-15.3,0.5]	[2,7]	[-20.3,-1.5]
SMO	[3.7,16.7]	[-4.1,9.7]	[11,19]	[3.2,12]	[4,11]	[-3.8,4]
OSF	[0,10.7]	[-12.7,0.2]	[0,6]	[-12.7,-4.6]	[2,6]	[-10.7,-4.6]
OA	[9.1,16.7]	[-0.8,11.5]	[11,31]	[1.1,25.8]	[24,42]	[14.1,36.8]
SC	[3.7,14.4]	[-3.3,12]	[4,11]	[-3,8.5]	[4,13]	[-3,10.5]
MRM	[16.3,25.9]	[5.5,21.1]	[19,22]	[8.2,17.2]	[18,22]	[7.2,17.2]
TL	[3.7,13]	[-3.9,8.5]	[2,9]	[-5.6,4.6]	[4,11]	[-3.6,6.6]
ECSA	[11.1,16.7]	[-7.4,0.7]	[7,15]	[-11.6,-1]	[9,13]	[-9.6,-3]
TWM	[3.7,14.8]	[-20,-6.1]	[2,8]	[-21.7,-12.9]	[6,9]	[-17.7,-11.9]

Source: own elaboration.

The middle point of the interval numbers and indicators are shown in Table 13.

Table 13: Times allocated and deviations calculated by interval numbers' middle points for SME3.

	July	August	September	October	November	December
VRM	-9.7	-7.5	-5.2	-8.9	-7.4	-10.9
SMO	-5.0	4.2	5.6	2.8	7.6	0.1
OSF	-9.8	-6.7	-3.3	-6.3	-8.6	-7.6
OA	28.1	19.9	11.0	5.3	13.4	25.4
SC	6.9	8.2	6.4	4.3	2.8	3.8
MRM	14.9	8.7	11.7	13.3	12.7	12.2
TL	-0.4	4.3	-1.4	2.3	-0.5	1.5
ECSA	-5.2	-12.7	-9.9	-3.4	-6.3	-6.3
TWM	-13.0	-10.8	-11.2	-13.0	-17.3	-14.8

Source: own elaboration.

Finally, Table 14 shows the actual impact that following the recommendations generated on the KPIs of SME3.

Table 14: Impact of the methodology on the SME3'S KPIs.

KPI	June	July	August	September	October	November	December
Net Sales	-48%	-11%	-50%	-100%	-81%	-8%	-25%
Customers	-44%	-11%	-50%	-100%	-80%	-100%	-4%
Gross Profit	-57%	-42%	-59%	-100%	-79%	18%	-35%
Margin on Sales	-17%	-34%	-16%	0%	9%	11%	-13%
Purchase Frequency	0%	0%	-25%	-100%	-50%	0%	-25%
Sales per Customer	0%	0%	-25%	-100%	-50%	0%	-25%
Costs of Sale	-52%	-14%	-43%	-100%	-82%	9%	-9%
Operating Costs	-33%	26%	-49%	-100%	-97%	-78%	-77%
Operating Profit	-48%	-26%	-65%	-100%	-68%	38%	3%

Source: own elaboration.

IV. CONCLUSIONS AND RECOMMENDATIONS

The implementation of the comprehensive time management methodology in several SMEs revealed interesting and instructive results that reflected both the strengths and limitations of the proposed decision support system in real-world applications. This was particularly highlighted through the assessments documented in Tables 2, 3, 4, 5, and 6. These tables demonstrated that the system is theoretically sound, while facing practical difficulties during implementation.

A managers' learning curve was noted, reflected in the monthly deviations from the recommended time allocations and showing that data-driven decision models require not only technical training but also organizational preparation and cultural adaptability.

The analysis of the three SMEs revealed heterogeneous improvements in key performance indicators, such as net sales, operating costs, and accounts receivable cycles. These variations are mainly explained by differences in the effectiveness with which each manager adopted and implemented the system's recommendations.

For example, SME 1, which is a frozen food distributor, showed a gradual adaptation to the model, while operating costs progressively increased. Although a slight improvement in compliance with recommendations was observed, the fluctuation of key performance indicators (KPIs) indicated that improvements were limited due to organizational inertia and partial adherence.

On the other hand, SME 2, a supplier of industrial maintenance, repair, and operations (MRO) materials, continued to exhibit large discrepancies between actual and recommended time spent. The company, although formalized, was rigid, which hindered behavioral adaptation. While resources were available to implement the model, management conservatism and routines limited significant improvements.

Finally, SME 3, a micro-enterprise in the food service sector, reported quick but erratic responses. Although its small size allowed for flexibility in applying the methodology, process instability and low management capacity generated volatile results, with notable improvements in some months and, in others, complete performance collapses.

These results indicate that organizational context is a critical factor for the effectiveness of decision support systems: the same methodology can produce divergent results depending on the company's size, culture, and managerial flexibility. The effectiveness of this methodology varied in the case studies due to several factors:

- Technological and administrative maturity: Companies with structured processes took longer to implement the methodology, but subsequently, their long-term performance was very stable. Companies less than five years old were more agile, although they lacked consistency and formal mechanisms to maintain the improvement process.
- Managerial culture and leadership style: The data obviously indicate that many managers persisted in prioritizing their previous activities, even when the optimization suggested otherwise. It seems that cognitive bias and low tolerance for algorithmic recommendations limited the system's potential.
- Human resource structure and workload distribution: In smaller organizations, where managers perform various operational functions, the theoretical redistribution of time often proved unfeasible. The lack of delegation capacity reduced the system's practical impact on strategic and financial indicators.

Furthermore, all case studies exhibited nonlinear trajectories in key performance indicators (KPIs), reflecting the dynamic interaction between behavioral adaptation and structural constraints. In some cases, improvements in the accounts receivable cycle or profit margin are offset by increased operating costs or decreased sales efficiency. These inconsistencies highlight the need to complement optimization models with organizational change management to ensure that structural and behavioral adjustments evolve in a coordinated manner.

Theoretically, this study confirms that value function theory and differential evolution can be combined into an advanced approach for managerial optimization under conditions of uncertainty. However, it also reveals the limitations of purely technical interventions when decision-making is deeply influenced by cultural and organizational dynamics.

Therefore, in practice, the results indicate that decision-support technologies must be accompanied by organizational development strategies that include training, leadership engagement, and ongoing support mechanisms. The heterogeneity of results among SMEs demonstrates that success depends less on the mathematical rigor of the methodology and more on the organization's ability to internalize and institutionalize new practices.

The comprehensive time management system was theoretically sound and promising in practice, but its actual effectiveness varied considerably among SMEs. The divergence in results underscores that:

- Technology and optimization models are only as effective as the managerial capacity and organizational culture that underpin them.
- Continuous feedback, training, and adaptation are essential for sustained improvement.
- Decision support methodologies must be adapted to the scale, maturity, and specific cultural characteristics of each SME to maximize their impact.

Therefore, future research should focus on hybrid models that integrate quantitative optimization with qualitative organizational interventions, thereby bridging the gap between algorithmic decision support and human-centered management practices.

V. REFERENCIAS

[1] M. Köksalan and S. B. Özpeynirci, “An interactive sorting method for additive utility functions,” Comput Oper Res, vol. 36, no. 9, pp. 2565–2572, 2009, doi: 10.1016/j.cor.2008.11.006.

[2] S. Das and P. N. Suganthan, “Differential evolution: A survey of the state-of-the-art,” IEEE transactions on evolutionary computation, vol. 15, no. 1, pp. 4–31, 2010, doi: 10.1109/TEVC.2010.2059031.

[3] S. Greco, V. Mousseau, and R. Słowiński, “Multiple criteria sorting with a set of additive value functions,” Eur J Oper Res, vol. 207, no. 3, pp. 1455–1470, 2010, doi: 10.1016/j.ejor.2010.05.021.

[4] R. Storn and K. Price, “Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces,” Journal of global optimization, vol. 11, no. 4, pp. 341–359, 1997, doi: 10.1023/A:1008202821328.

[5] T. Krink and S. Paterlini, “Multiobjective optimization using differential evolution for real-world portfolio optimization,” Computational Management Science, vol. 8, no. 1–2, pp. 157–179, 2011, doi: 10.1007/s10287-009-0107-6.

[6] J. S. García, Fundamentos de marketing digital. Comunicación Social Ediciones y Publicaciones, 2016.

[7] S. Dutta, B. Lanvin, L. Rivera León, and S. Wunsch-Vincent, “Global innovation index 2023: Innovation in the face of uncertainty,” 2023. [Online]. Available: https://www.wipo.int/edocs/pubdocs/en/wipo-pub-2000-2023-en-main-report-global-innovation-index-2023-16th-edition.pdf.

[8] J. S. Eccles and A. Wigfield, “From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation,” Contemp Educ Psychol, vol. 61, p. 101859, 2020, doi: 10.1016/j.cedpsych.2020.101859.

[9] H. D. Garc\'\ia-Juárez, C. Bustamante-Ochoa, F. Del Carpio-Delgado, and Y. M. Bravo-Chávez, “Metodolog\'\ia PHVA para el mejoramiento de la gestión de los procesos en una empresa de Productos Naturales,” AiBi Revista de Investigación, Administración e Ingenier\'\ia, vol. 12, no. 1, pp. 109–121, 2024.

[10] A. P. Piotrowski, J. J. Napiorkowski, and A. E. Piotrowska, “Particle swarm optimization or differential evolution—A comparison,” Eng Appl Artif Intell, vol. 121, p. 106008, 2023, doi: 10.1016/j.engappai.2023.106008.

[11] Q. Gu, S. Li, and Z. Liao, “Solving nonlinear equation systems based on evolutionary multitasking with neighborhood-based speciation differential evolution,” Expert Syst Appl, vol. 238, p. 122025, 2024, doi: 10.1016/j.eswa.2023.122025.

[12] Q. Sui, Y. Yu, K. Wang, L. Zhong, Z. Lei, and S. Gao, “Best-worst individuals driven multiple-layered differential evolution,” Inf Sci (N Y), vol. 655, p. 119889, 2024, doi: 10.1016/j.ins.2023.119889.

[13] T. Dashela, “The analysis of theme and rheme in short story of sleeping beauty with a systemic functional approach,” SALEE: Study of Applied Linguistics and English Education, vol. 2, no. 1, pp. 11–28, 2021.

[14] T. Sunaga, Theory of an Interval Algebra and its Applications to Numerical Analysis. RAAG Memoirs, 1958.

[15] R. E. Moore, Interval arithmetic and automatic error analysis in digital computing. Stanford University, 1963.

[16] C. Yang, “Interval strategy-based regularization approach for force reconstruction with multi-source uncertainties,” Comput Methods Appl Mech Eng, vol. 419, p. 116679, 2024, doi: 10.1016/j.cma.2023.116679.

[17] T. Reilly, Making hard decisions with DecisionTools. Duxbury Thomson Learning, 2001.

[18] G. E. Dieter and L. C. Schmidt, “Engineering Design, Fourth Editions,” 2009, McGraw-Hill.

[19] C. Y. Gómez-Llanez, N. R. Diaz-Leal, and C. R. Angarita Sanguino, “A comparative analysis of the ERP tools, Odoo and Openbravo, for business management,” Aibi Revista de Investigación, vol. 8, no. 3 (2020), pp. 145–153, 2020.

[20] A. L. Hernández-Abreo, B. D. Abreo-Pinzón, and L. F. Bohorquez-Chacón, “Programa responsabilidad social empresarial: empresa Global Service & Business SAS,” Aibi revista de investigación, administración e ingenier\'\ia, vol. 6, no. 2, pp. 2–12, 2018.

[21] A. Aguilera, A. E. Moreno, E. Solares, J. A. Lara-Pérez, and C. Tolentino, “Time Allocation to Management Activities of Retail Msmes Through an Intelligent System,” International Journal of Intelligent Systems and Applications in Engineering, vol. 12, no. 4, pp. 356–365, 2024, [Online]. Available: https://ijisae.org/index.php/IJISAE/article/view/6222.