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Time Allocation to Management Activities of Retail Msmes Through an Intelligent System

Alberto Aguilera[1], Armando Esquinca Moreno[2], Efrain Solares*[3], Jorge Alfonso Lara-Pérez[4], Carlos Tolentino[5]

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Abstract: Effectively handling a manager's time is critical for organizational success. This paper describes a methodology that uses cutting-edge decision support to offer flexible recommendations grounded in the unique context of Ciudad Juárez, México. The methodology incorporates manager preferences, determining the value of activities through the theory of value functions and performs an optimization based on differential evolution. This methodology ensures practical applicability, handling multiple activities, group decisions, and uncertainties prevalent in the dynamic business landscape. Validating the approach, a real case study involving Ciudad Juárez managers provides contextual evidence. The proposed system's performance is evaluated based on the satisfaction levels of participating managers. This research contributes to decision and social sciences by introducing a system designed for handling managerial times in a culturally specific environment. The study emphasizes the adaptability of the system to diverse managerial activities, making it a valuable tool for decision-makers.

Keywords: *Evolutionary algorithms, time management, uncertainty management*

Introduction

Managers, as key decision-makers, wield expert knowledge pivotal in the allocation of their own time. Their understanding, often implicitly informed by holistic insights, allows them to make crucial judgments in this regard. Of course, leveraging the collective expertise of managers within similar contexts holds the potential for even more informed decisions. However, the practical reality is that managers frequently allocate a significant portion of their time to immediate and pressing issues, primarily day-to-day operations. This tendency can have severe consequences, notably relegating critical strategic aspects, such as time allocation, which holds substantial implications for overall business competitiveness and strategic advancement. Recognizing the importance of handling managerial times, this research describes a methodology designed to optimize this intricate process, with a focus on the dynamic business environment of Ciudad Juárez, Mexico.

In Mexico, according to the National Institute of Statistics and Geography ([1]), Micro, Small and Medium Enterprises (MSME) represent 99.8% of all companies; 94.9% are Microenterprises that employ 4 out of every 10 people. The proportions of MSMEs do not differ substantially in other countries, as stated by [2] who mentions that in 2014 in Spain they amounted to 99.90% compared to 99.80% in the European Union. The retail sector in Mexico is the one with the most companies, representing 57% compared to 32% of the Services sector and 11% of Industry. Retail trade involves those businesses that primarily engage in the activity of purchasing products from other organizations with the intention of reselling those goods to private households, generally without transformation. The retail process is the final step in the distribution of goods [3]. Commerce in general contributes the largest number of Economic Units, and is the one that absorbs the most employed personnel. However, at the national level, their life expectancy at birth is only 6.9 years compared to 8 in the Services sector and 9.7 in the Manufacturing sector. The main causes are related to education. Only one in two people in microenterprises has basic education, one in two does not use accounting packages or the services of an accountant compared to 93% of SMEs, 12.5% of Micros monitor 3 to 5 indicators compared to 28 % of SMEs; the life expectancy of commerce in the state of Chihuahua is only 5.8 years;

[1] *Professor, Faculty of Political and Social Sciences, Autonomous University of Chihuahua – 31160, Mexico*
Email: albertoat356@gmail.com
ORCID ID : 0000-0003-4428-380X
[2] *Professor, Faculty of Political and Social Sciences, Autonomous University of Chihuahua – 31160, Mexico*
Email: arquin@uach.mx
ORCID ID : 0000-0002-8396-589X
[3] *Professor, Faculty of Accounting and Administration, Autonomous University of Coahuila – 27000, Mexico*
Email: efrain.solares@uadec.edu.mx
ORCID ID: 0000-0003-1310-8638
[4] *Professor, Institute of Social Sciences and Administration, University of Ciudad Juárez – 32300, Mexico*
Email: jorge.lara@uacj.mx
ORCID ID: 0000-0003-1474-1312
[5] *Professor, Technological Institute of Mexico Saltillo campus – 25280, Mexico*
Email: carlos.th@saltillo.tecnm.mx
ORCID ID: 0009-0005-3670-5410

** Corresponding Author Email: efrain.solares@uadec.edu.mx*

mortality in the first year is 37% (INEGI, 2023). According to the National Directory of Economic Units (DNUE) [6], in Cd. Juárez, Chihuahua, there are 16,590 Economic Units in the retail sector (17,899 including Wholesale), 13,203 in services and 2,589 in the manufacturing sector.

In the Global Innovation Index 2023, Mexico holds the 58th position among 132 countries, ranking 11th among upper-middle-income nations and third in Latin America, following Brazil and Chile [7]. This underscores the imperative to continue fostering innovation in economic activities, a key driver for elevating quality standards and regional competitiveness. According to the 2018 report "Towards an AI strategy in Mexico: Harnessing the AI revolution", stagnating productivity in Mexico is preventing the economy from achieving significant gains, and one solution to this productivity problem could be the advancement in innovation, for example, through computational intelligence [8]. Mexico faces automation that will impact 19% of jobs (9.8 million) in two decades, with manufacturing and construction being the most affected; this automation will require careful management that implies, for example, greater gender equality [mexico2018towards]. In terms of preparation in terms of artificial intelligence (AI) for this type of automation, Mexico occupies only 22nd place on the list of 35 countries of the Organization for Economic Cooperation and Development (OECD), excelling in infrastructure, but lagging in skills and innovation [8]. Continuous improvement in processes and products, coupled with the identification of factors conducive to fostering innovation, is essential [9].

Acknowledging the evolving landscape, the OECD emphasizes that traditional innovation strategies, such as strengthening local firms' R&D capacities, may no longer suffice. In this context, scholars stress that innovation, defined as the creation and enhancement of products or processes stemming from creative ideas, is a complex, crucial, and high-priority process for businesses that involves providing something new, beneficial in the long term, emanating from intelligent thoughts [10], [11].

Recognizing the multifaceted nature of innovation, [12] emphasize the role of managers in creating an environment conducive to stimulating ideas and projects. In this regard, effective time management is crucial for the success of any organization, and it plays a significant role in the responsibilities of managers. The way managerial time is handled directly impacts the overall productivity, efficiency, and success of a business [13].

Incorporating uncertainty into models to handle managerial times can be achieved through various methods, among which fuzzy numbers stand out as a significant approach. Fuzzy numbers are particularly useful in situations where the exact value of a number is unknown, yet there is knowledge about the range it occupies and its distribution. This method has been applied across diverse fields, from robotics to finance, demonstrating its versatility. For instance, researchers have utilized fuzzy numbers to evaluate investment risks [14] and to prioritize alternatives [15], showcasing the method's ability to handle ambiguity in numerical data effectively. Another method to represent uncertainty, which may be more straightforward than fuzzy numbers, involves the use of interval numbers. Interval numbers specify the range within which an uncertain quantity resides, employing uniform distributions for this purpose. The simplicity of interval theory lies in its capacity to compare interval numbers directly and intuitively, determining whether one is greater than or equal to another [16]. This approach has been beneficial in various applications, such as risk assessment in projects based on failure probabilities [17]. The utility of interval numbers extends to financial analysis, where Solares et al. [18] have leveraged their properties to evaluate and juxtapose investment portfolios.

The present paper describes the application of a methodology aimed at optimizing managerial time allocation within the unique and dynamic business environment of Ciudad Juárez, Mexico. The main novelties and contributions of this study are multi-faceted, reflecting innovation in decision support systems and providing a culturally nuanced understanding of managerial practices in this region while handling uncertainty in the recommendations through interval analysis theory. Firstly, the study describes an approach that integrates manager preferences with the theory of value functions to prioritize activities, thereby personalizing the optimization process. This customization is validated with a real-case study involving Ciudad Juárez managers, the paper demonstrates practical applicability and contextual relevance. Secondly, the research contributes to decision and social sciences by offering a system designed to navigate the intricacies of handling managerial times in a context-specific manner. This system's adaptability across diverse managerial activities showcases its potential as a valuable tool for decision-makers, particularly in environments similar to Ciudad Juárez.

The paper proceeds with Materials and Methods in Section 2, detailing the approach's design and implementation, followed by the results in Section 3, presenting the findings from Ciudad Juárez managers. It concludes with some discussion and conclusions in Section 4, synthesizing the insights, evaluating the methodology's impact, and suggesting future research directions.

Materials and methods

In this section, we describe a framework for modeling and

optimizing managerial time allocation by integrating value functions, interval numbers, and differential evolution. This methodology is specifically tailored to capture the nuanced preferences of managers and the inherent uncertainties in determining optimal time allocations for various managerial activities.

Value Theory

In decision-making, value theory, often integrated within the broader scope of decision theory, addresses how individuals and organizations assess the worth or utility of different options to make choices that maximize perceived value [19], [20]. This involves understanding what is valued, the intensity of that value, and the trade-offs willing to be made between competing values when decisions are required. Value theory in this context is concerned with identifying and prioritizing values that decision-makers consider important, such as efficiency, sustainability, profit, ethical considerations, or customer satisfaction. The theory posits that decision-making is a process of evaluating the potential outcomes of various alternatives based on the values assigned to different criteria or objectives. These values may be quantifiable, as in cost-benefit analysis, or qualitative, reflecting ethical principles, societal norms, or personal preferences. Value theory in decision-making underlines the importance of value functions, which are used to translate the levels of different criteria into a common scale of value, facilitating comparison and aggregation. This approach helps in structuring decision problems, making explicit the values guiding decisions, and providing a rational framework for choosing among alternatives. Value theory in decision-making emphasizes the subjective nature of value, acknowledging that what is considered valuable can vary widely among individuals and organizations. It also deals with how values are ranked or weighted, which is crucial in multi-criteria decision-making (MCDM) problems where trade-offs between conflicting criteria must be negotiated.

Value functions [21], the central concept in value theory, serve as a foundational element in our approach, enabling the quantitative representation of managerial preferences across different activities. These functions offer a straightforward yet powerful means to encapsulate the relative importance or desirability managers assign to their tasks. The utilization of value functions is particularly pertinent in this context due to the challenges associated with articulating a direct mathematical relationship between the allocation of time to specific activities and their subsequent impact on organizational goals.

Through the lens of value functions, in this work we can effectively translate the qualitative insights and expert judgments of managers into a structured, quantitative format. This process involves assigning a numerical value to each possible decision alternative, thereby facilitating a ranked order of preferences that aligns with the manager's perspectives and priorities. The underlying premise of this approach is the creation of a real-valued function that embodies the decision-maker's preferences, transforming the attributes of each option into a numeric score that reflects its relative merit or desirability.

By adopting this sophisticated modeling technique, we aim to provide a robust and flexible framework that not only respects the complex judgment processes of managers but also offers a systematic method for navigating the decision-making landscape characterized by competing priorities and limited time resources.

Interval Analysis Theory

The foundational concept of Interval Analysis Theory, developed independently by [22] and [23], revolves around the interval number concept. This concept is a powerful tool for dealing with numerical quantities whose exact values are not precisely known. By using a range of numbers to represent all possible values a quantity might assume, an interval number symbolizes an indeterminate value within a specified set of numbers. For example, a quantity denoted by ι with an uncertain real value lying between lower bound i^- and upper bound i^+ is represented as an interval number I = $[i^-, i^+]$. Any value r that falls within this range is considered a realization of I. This method also allows for the conversion of a specific real number, q, into an interval number as $[q, q]$.

Building on the foundational operations involving interval numbers I = $[i^-, i^+]$ and J = $[j^-, j^+]$, we outline their addition, subtraction, multiplication, and division as follows:

- Addition: I + J = $[i^- + j^-, i^+ + j^+]$,
- Subtraction: I - J = $[i^- - j^+, i^+ - j^-]$,
- Multiplication: I × J = $[\min\{i^-j^-, i^-j^+, i^+j^-, i^+j^+\}, \max\{i^-j^-, i^-j^+, i^+j^-, i^+j^+\}]$,
- Division: I ÷ J = $[i^-, i^+] \times [1/j^-, 1/j^+]$.

[16] introduced a method for determining the precedence among interval numbers through a possibility function that evaluates the likelihood of one interval being equal to or greater than another. The possibility that interval I is at least as great as interval J is determined by:

$$P(\mathrm{I} \geq \mathrm{J}) = \begin{cases} 1 & \text{if } p_{IJ} > 1, \\ p_{IJ} & \text{if } 0 \leq p_{IJ} \leq 1, \\ 0 & \text{if } p_{IJ} < 0. \end{cases}$$

Where $p_{IJ} = \frac{i^+ - j^-}{(i^+ - i^-)+(j^+ - j^-)}$, and $(i^+ = i^- = i \text{ and } j^+ = j^- = j) \Rightarrow P(\mathrm{I} \geq \mathrm{J}) = \begin{cases} 1 & \text{if } i \geq j, \\ 0 & \text{otherwise.} \end{cases}$

This formulation allows decision-makers to gauge the

robustness of the assertion that I is not less than J, underpinning the credibility of such comparisons in uncertain conditions.

Further analysis reveals intriguing properties related to the comparison and order of interval numbers, facilitating a deeper understanding of their relational dynamics. These properties enhance the applicability of interval theory in decision-making, offering a structured approach to manage uncertainty in scenarios where precise values are elusive, thereby supporting more informed and robust decision processes.

Optimization techniques

Differential Evolution (DE) stands out as a robust optimization algorithm, highly suitable for tackling optimization challenges with continuous decision variables. Its efficacy and efficiency are particularly noted in contexts where traditional mathematical optimization techniques fall short due to their exhaustive requirements. Although DE aims to find optimal solutions, it is typically geared towards identifying suboptimal yet practically satisfactory solutions for the user. DE operates on the principle of generational progression, mirroring the process of biological evolution. It works with a population of potential solutions, referred to as individuals or agents, navigating through the solution space to enhance these solutions over generations. The algorithm is driven by key parameters: the crossover probability (CR) within the range [0, 1], the differential weight (F) within [0, 2], and the population size (Psize), which is set to be four or more. Each individual in the population is depicted as a real-valued vector with m components, where each component z_i corresponds to the value of the ith decision variable.

The DE algorithm unfolds in several steps, beginning with the initialization of individuals at random positions within the search space. This random assignment ensures that each decision variable respects the associated constraints. The algorithm proceeds iteratively until a predefined termination criterion, such as a specified number of iterations, is met. Throughout these iterations, DE continuously seeks to improve the population by employing a set of operations ($F(\cdot)$ denotes a function to assess the quality of solutions and is provided in Section 3):

1. For each individual z in the population, select three other distinct individuals a, b, c, ensuring no overlap with z.
2. For every decision variable, generate a random number u within [0, 1]. If u is less than the crossover probability CR or the variable index matches a randomly chosen index r, update the variable using the formula $y_i = a_i + F(b_i - c_i)$; otherwise, retain the original value z_i.
3. Evaluate the quality of the new solution y against the current solution z using a predefined fitness function. If the new solution demonstrates equal or better fitness, it replaces the current solution in the population.
4. After all individuals have undergone evaluation and potential replacement, identify and select the individual with the highest fitness within the population.

By incorporating DE, our proposed approach leverages its adaptability and iterative refinement capability to allocate the most suitable times to managerial activities in Ciudad Juárez, México. This methodology, grounded in the value and interval theories, aims to systematically explore and optimize the allocation of managerial time, ensuring alignment with the complex and dynamic priorities characteristic of managerial responsibilities.

Results

The objective of our research was to delve into the intricacies of managerial time allocation within the unique business environment of Ciudad Juárez, México. Recognizing the pivotal role that efficient time management plays in enhancing organizational productivity and effectiveness, we sought to identify and analyze several key aspects of managerial activities and preferences. Our study was designed with the intent to uncover a comprehensive understanding of the following critical areas, identified as a result of this research:

1. Identification of common managerial activities: Understanding that managers in Ciudad Juárez engage in a diverse array of activities, our primary aim was to ascertain the most common set of activities as identified by the managers themselves. This step was crucial for establishing a baseline of tasks that are universally acknowledged as significant across various industries within the region.
2. Assessment of value assignments to activities: Beyond identifying the common managerial tasks, we aimed to explore the subjective value that managers assign to each of these activities. Recognizing that not all tasks hold equal importance, this analysis sought to reveal the perceived value or priority that managers attribute to specific activities, providing insights into their decision-making processes and priority-setting mechanisms. In the end, such a subjective information will provide context-dependent characteristics that the proposed approach will exploit to provide expert recommendations.
3. Determination of constraints on time allocations:

An integral part of effective time management involves understanding the limitations and constraints that managers face in their daily operations. Our study, therefore, focused on determining the set of constraints that managers in Ciudad Juárez impose on their time allocations. By identifying these constraints, we aimed to shed light on the challenges and limitations that influence managerial time allocation strategies and model them within the proposed approach.

4. Provision of flexible time allocation recommendations: With a clear understanding of common activities, their assigned values, and the constraints impacting time allocations, our final objective was to provide flexible recommendations regarding the proportion of time that managers should allocate to each activity. Recognizing the dynamic nature of managerial roles and the fluctuating demands of the business environment, these recommendations were designed to offer guidance while allowing for adaptability and adjustments based on real-time needs and priorities.

Below, we describe the results of such a proposal.

Common managerial activities observed

In the initial phase of our methodology, the study revealed that managers across various sectors in Ciudad Juárez prioritize a core set of activities for resource allocation. These activities include

a) Operational Administration covers the day-to-day management of internal processes and systems that keep the organization running smoothly. This includes overseeing administrative tasks, optimizing operational workflows, and ensuring that internal resources are effectively utilized.

b) Talent and Workforce Management covers the strategies and practices employed to recruit, develop, and retain a skilled and engaged workforce. It includes human resources planning, employee development programs, performance management, and fostering a positive organizational culture that supports the strategic objectives of the organization.

c) Sales and Marketing Oversight involves the strategic promotion of products or services and the management of sales activities to foster business growth. This includes identifying target markets, developing marketing strategies, and driving sales efforts to increase brand awareness and revenue.

d) Organizational Strategy Formulation refers to the process of setting long-term goals and determining the necessary approaches to achieve these objectives. It involves analyzing internal and external environments, making strategic decisions, and implementing plans to steer the organization towards its vision.

e) Excellence and Client Satisfaction Assurance involves the continuous improvement of product quality and service delivery to meet or exceed customer expectations. It encompasses quality control processes, customer feedback mechanisms, and service excellence initiatives to enhance customer satisfaction and loyalty.

f) Vendor Relationship Management encompasses the comprehensive oversight and coordination of all facets related to procuring goods and services from suppliers. This involves negotiating contracts, ensuring the timely delivery of high-quality products, and maintaining beneficial relationships with suppliers to achieve cost-effectiveness and reliability in supply chains.

g) Stock Control entails managing the acquisition, storage, and distribution of inventory. It involves monitoring stock levels, forecasting demand, and implementing strategies to minimize costs associated with holding and replenishing inventory, ensuring that products are available to meet customer demand without excessive surplus.

h) Monetary Resources Management focuses on optimizing the organization's financial performance, particularly concerning cash flow. It encompasses planning, monitoring, and managing income and expenditures to maintain financial health, ensure liquidity, and support operational and strategic goals.

i) Tactical Leadership involves guiding the organization through the development and implementation of specific strategies to navigate competitive markets and achieve business objectives. It includes setting strategic directions, aligning resources, and adapting tactics in response to changing market dynamics.

This comprehensive list underscores the multifaceted nature of managerial responsibilities, spanning across operational, strategic, and human capital dimensions.

Value assignments to activities

To further our understanding of these activities, we employed the Swing method [24], [25], an analytical approach designed to quantify the subjective values managers assign to each activity. This method facilitated a systematic elicitation of preferences, enabling us to construct an additive value function that encapsulates the

relative importance of each managerial activity. The findings from this exercise revealed diverse perspectives among managers regarding the desirability of allocating time to specific activities.

Vendor Relationship Management emerged as a high-priority area for some managers, with values ranging significantly from 2.32% to as high as 20.66%, indicating a broad recognition of its importance in shaping organizational direction and success. Similarly, Sales and Marketing Oversight was highly valued, with percentages reaching up to 28.08%, reflecting its pivotal role in driving business growth and customer engagement.

Conversely, Operational Administration and Stock Control were assigned lower values by some managers, suggesting a perception of these activities as less critical to immediate business outcomes. However, variations in the assigned values across all activities highlight the unique contexts and strategic focuses of different managers and their respective organizations.

The aggregate results, which integrate the values assigned by the managers to each activity, provide a nuanced view of managerial priorities in Ciudad Juárez. These findings not only reflect the diverse challenges managers face but also underscore the critical need for tailored time allocation strategies that can accommodate the dynamic and complex nature of managerial work. The diverse valuation of activities suggests a strategic dimension to time management, where the alignment of resource allocation with organizational goals and market demands becomes a key driver of managerial effectiveness and organizational performance. The complete information is provided in Table 1.

Upon establishing the specific values allocated by the managers to the activities based on their desirability for time investment, our approach aims to consolidate these individual preferences into a unified framework. This is achieved by assigning a distinct interval number to each activity, delineated by the lowest and highest weights assigned by the managers, as illustrated in Table 2. The purpose behind aggregating managers' references into this consolidated model is to create a comprehensive view that reflects the collective insights and experiences of managers operating within analogous organizational and contextual frameworks. By adopting this method, we suggest that the amalgamated expertise of these managers serves as a valuable guide in recommending how time should be optimally distributed across various managerial tasks. This approach not only acknowledges the diversity of managerial perspectives but also leverages their collective wisdom to

Table 1. Opinions of managers regarding the value of each activity

Manager	*Vendor Relationship Management*	*Sales and Marketing Oversight*	*Organizational Strategy Formulation*	*Operational Administration*	*Stock Control*	*Monetary Resources Management*	*Tactical Leadership*	*Excellence and Client Satisfaction Assurance*	*Talent and Workforce Management*
1	0.02	0.19	0.33	0.02	0.09	0.19	0.02	0.07	0.07
2	0.04	0.12	0.14	0.20	0.06	0.02	0.18	0.10	0.16
3	0.09	0.09	0.15	0.11	0.09	0.09	0.13	0.11	0.12
5	0.00	0.05	0.63	0.21	0.00	0.11	0.00	0.00	0.00
6	0.05	0.13	0.18	0.19	0.01	0.02	0.00	0.24	0.19
7	0.00	0.14	0.14	0.14	0.14	0.00	0.14	0.14	0.14
8	0.07	0.08	0.16	0.08	0.12	0.16	0.10	0.13	0.10
9	0.21	0.04	0.14	0.00	0.02	0.10	0.00	0.23	0.25
10	0.05	0.16	0.21	0.05	0.11	0.21	0.11	0.05	0.05
11	0.13	0.11	0.13	0.13	0.10	0.14	0.13	0.13	0.01
12	0.05	0.09	0.18	0.14	0.05	0.18	0.14	0.05	0.14
13	0.08	0.08	0.13	0.13	0.08	0.15	0.14	0.08	0.14
14	0.06	0.11	0.11	0.06	0.00	0.22	0.11	0.11	0.22
15	0.11	0.13	0.13	0.08	0.08	0.13	0.13	0.11	0.11
16	0.12	0.12	0.13	0.10	0.11	0.11	0.10	0.11	0.11
17	0.08	0.12	0.14	0.11	0.09	0.11	0.14	0.07	0.14
18	0.07	0.08	0.21	0.07	0.11	0.08	0.11	0.11	0.16
19	0.12	0.12	0.14	0.12	0.11	0.13	0.14	0.12	0.00
20	0.08	0.05	0.22	0.11	0.05	0.11	0.16	0.11	0.11
21	0.12	0.12	0.10	0.08	0.08	0.15	0.08	0.12	0.15
22	0.05	0.05	0.32	0.21	0.05	0.11	0.05	0.05	0.11
23	0.03	0.11	0.18	0.06	0.03	0.17	0.20	0.09	0.14
24	0.15	0.15	0.27	0.03	0.00	0.18	0.21	0.00	0.00
25	0.00	0.08	0.19	0.13	0.10	0.06	0.17	0.12	0.15
26	0.06	0.08	0.18	0.02	0.12	0.20	0.16	0.04	0.14
27	0.13	0.13	0.13	0.07	0.04	0.04	0.27	0.08	0.09
28	0.13	0.11	0.19	0.09	0.02	0.15	0.08	0.06	0.17
29	0.07	0.09	0.12	0.12	0.06	0.10	0.11	0.08	0.25
30	0.09	0.26	0.17	0.00	0.13	0.13	0.09	0.13	0.00
31	0.15	0.07	0.22	0.11	0.11	0.06	0.04	0.04	0.19
32	0.11	0.11	0.12	0.11	0.11	0.11	0.11	0.11	0.11
33	0.06	0.11	0.16	0.16	0.06	0.16	0.22	0.02	0.04
34	0.14	0.12	0.15	0.11	0.09	0.00	0.00	0.21	0.18

inform a more nuanced and effective time allocation strategy for organizations sharing similar characteristics and challenges.

Table 2. Opinions of managers in the form of interval numbers

Activity	Minimum Value (%)	Maximum Value (%)
Vendor Relationship Management	0.02	0.21
Sales and Marketing Oversight	0.04	0.26
Organizational Strategy Formulation	0.10	0.63
Operational Administration	0.02	0.21
Stock Control	0.01	0.14
Monetary Resources Management	0.02	0.22
Tactical Leadership	0.02	0.27
Excellence and Client Satisfaction Assurance	0.02	0.24
Talent and Workforce Management	0.01	0.25

Determination of constraints on time allocations

A crucial step involves identifying the specific constraints that managers wish to apply to the optimization problem. Through the case study conducted, it became evident that managers are keen on establishing precise boundaries for time dedicated to each managerial activity. This preference stems from the understanding that all nine core activities, previously identified, require a balanced allocation of time — neither too brief to be ineffective nor excessively prolonged to the point of diminishing returns.

This balanced approach to time allocation underscores the managers' collective insight into the nature of these activities. They recognize that each task, while essential, has an optimal engagement window that maximizes effectiveness and contributes to overall organizational efficiency. Setting these time boundaries is not arbitrary but is deeply informed by the managers' experiential knowledge of operational dynamics and the strategic importance of each activity.

The specific constraints that the managers proposed are meticulously documented in Table 3. These constraints are a testament to the managers' strategic intent to optimize resource allocation. By defining these limits, managers aim to ensure that each activity receives the attention it deserves, within a framework that promotes both efficiency and effectiveness. The establishment of these constraints is a strategic maneuver designed to prevent overcommitment to any single task at the expense of others and to avoid the pitfalls of under-engagement, where the potential value of an activity is not fully realized due to insufficient time allocation.

This thoughtful process of constraint determination aligns with the broader goal of achieving a harmonious balance in managerial efforts. It reflects a sophisticated understanding that optimal time allocation is critical to organizational success, necessitating a careful calibration of time investments across a diverse set of managerial responsibilities. Through this approach, the study aims to offer a nuanced perspective on managerial time allocation, providing a template that other organizations can adapt to enhance their operational efficiency and strategic execution.

Table 3. Constraints provided by the managers as proportions of time

Activity	Lowest Proportion	Highest Proportion
Vendor Relationship Management	9.0%	12.0%
Sales and Marketing Oversight	12.0%	12.8%
Organizational Strategy Formulation	12.0%	12.8%
Operational Administration	11.5%	12.0%
Stock Control	7.7%	8.0%
Monetary Resources Management	12.8%	16.0%
Tactical Leadership	10.3%	12.0%
Excellence and Client Satisfaction Assurance	11.5%	12.0%
Talent and Workforce Management	4.0%	11.5%

Flexible time allocation

In the concluding phase of our methodology, we deployed an advanced optimization strategy leveraging metaheuristic algorithms, specifically differential evolution, to ascertain the most effective distribution of time across managerial activities. This optimization process was fine-tuned with standard parameter settings to ensure the robustness and reliability of our approach. The crossover probability (CR) was calibrated at 0.9, illustrating a high likelihood of gene

crossover during the evolution process. The differential weight (F) was determined to be 0.8, indicating the influence of differential variations on the generation of new candidate solutions. Furthermore, the population size was set at 200, allowing for a diverse pool of potential solutions to explore the solution space comprehensively. The algorithm was allowed to iterate 100 times, ensuring ample opportunity for convergence towards optimal or near-optimal solutions.

The outcomes of applying this approach are detailed in Table 4, revealing insightful patterns about the time allocation preferences among managerial activities within the case study. Notably, the aggregate of the minimum value assignments falls below 100%, signifying that the lower bounds of time allocations for all activities collectively do not utilize the entire available time. Conversely, the summation of the maximum value assignments exceeds 100%, indicating that if all activities were pursued to their upper time limits, they would demand more than the total available managerial time.

This characteristic of the model's results underscores a pragmatic and flexible approach inherent in our optimization process. It acknowledges the dynamic nature of managerial responsibilities, where the necessity to prioritize certain activities over others can shift based on organizational needs, external pressures, or strategic focus adjustments. By providing recommendations within defined ranges, the model empowers managers with the flexibility to tailor their time allocations in response to real-time demands while maintaining the overall coherence of their strategic objectives. The recommendations, therefore, serve not as rigid prescriptions but as adaptable guidelines that support informed decision-making. This balance between flexibility and robustness in recommendations ensures that managers can make nuanced decisions that align with both immediate operational needs and long-term strategic goals, thereby optimizing the efficacy and efficiency of managerial activities.

Table 4. System's advice that maximizes the activities' value regarding the point of view of the managers in Ciudad Juárez, México

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

Discussion and conclusions

This study harnesses the potential of computational intelligence within a decision support system aimed at handling how managers allocate their time across various essential activities. By integrating advanced methodologies such as value function theory, interval theory, and evolutionary algorithms, our approach presented a novel solution to the challenge of optimizing managerial time allocation. The flexibility inherent in our model addresses the dynamic nature of managerial responsibilities, offering a tailored strategy that accommodates changing priorities and operational demands in the context of Ciudad Juárez, México. The application of this model in a case study involving organizations of varying sizes—from small to medium-sized—revealed its effectiveness in managing time allocation. Through this practical exploration, we demonstrated that the model not only meets the specific constraints set by managers but also enhances the total value derived from their time investment. Our findings underscore the model's capacity to provide actionable, adaptable recommendations that significantly improve managerial efficiency and, by extension, organizational performance.

One of the key insights from our research is the critical role of flexibility in managerial decision-making. Traditional decision support models often suffer from rigidity, offering a one-size-fits-all solution that fails to account for the unique contexts and fluctuating needs of different organizations. Our model challenges this norm by introducing a flexible framework that allows managers to

adjust their time allocation in real-time, ensuring that strategic priorities are consistently aligned with organizational goals. Moreover, our study highlights the untapped potential of computational intelligence in the domain of managerial support. Despite its widespread application across various fields, its use in enhancing managerial efficiency represents a relatively unexplored area. By pioneering the application of computational intelligence to this challenge, we open the door to further innovations that could transform organizational management practices.

The case study, while providing valuable insights, is limited to a specific context and a small sample of organizations. This raises questions about the generalizability of our findings and the model's applicability across different industries and organizational scales. Future research efforts should aim to address these limitations by conducting studies with a broader range of participants and exploring the model's effectiveness in various settings. Several avenues for further exploration are plausible. An in-depth analysis of the model's impact on organizational performance, both before and after implementation, would offer a more comprehensive understanding of its effectiveness. Additionally, incorporating more sophisticated modeling techniques, such as the outranking approach and fuzzy logic, could refine the model's recommendations and enhance its adaptability to complex decision-making scenarios. Adopting a statistical approach to optimize the model's parameters would further improve its accuracy and relevance to diverse organizational contexts.

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Author contributions

Alberto Aguilera: Conceptualization, Methodology, validation, formal analysis, writing—review and editing, supervision. **Armando Esquinca:** Methodology, formal analysis, investigation, data curation. **Efrain Solares:** Software, validation, writing—original draft preparation. **Jorge Lara:** Software, writing—review and editing, visualization. **Carlos Tolentino:** writing—review and editing, visualization

Conflicts of interest

None.

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