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An Intelligent System for Allocating Times to the Main Activities of Managers

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Abstract: Correctly allocating times to the main activities of a manager is a crucial task that directly affects the possibility of success for any company. Decision support based on state-of-the-art methods can lead to better performance in this activity. However, allocating times to managerial activities is not straightforward; the decision support should provide a flexible recommendation so the manager can make a final decision while ensuring robustness. This paper describes and assesses a novel approach where a search for the best distribution of the manager's time is performed by an intelligent decision support system. The approach consists of eliciting manager preferences to define the value of the manager's main activities and, by using a portfolio-like optimization based on differential evolution, obtaining the best time allocation. Aiming at applicability in practical scenarios, the approach can deal with many activities, group decisions, cope with imprecision, vagueness, ill-determination, and other types of uncertainty. We present evidence of the approach's applicability exploiting a real case study with the participation of several managers. The approach is assessed through the satisfaction level of each manager.

Keywords: time allocation; decision support system; computational intelligence; uncertainty management

MSC: 68T20

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1. Introduction

Time management is an issue that occupies the attention of individuals and society in general. So much importance is attached to time management that several countries have national surveys to measure it [1]. In Mexico, the National Survey on the use of time provides statistical information on the measurement of paid and unpaid work to make visible the importance of domestic work.

Managers' expert knowledge is often the main way how time is allocated to activities. These decision makers usually dominate most of the relevant information that, implicitly and holistically, allows them to make the required set of judgments. Furthermore, expert knowledge from other managers belonging to similar contexts could imply even better decisions. However, managers often dedicate most of their time to the most urgent issues, that is, day-to-day operations. This situation has the consequence that issues with the greatest impact on strategy and the increase in business competitiveness, as time allocation, are being relegated.

A poor time allocation by the manager of an organization can affect the person, the organization, and society in general. That is why various proposals recognize the importance of this managerial ability, but it is still an unsolved problem for many managers.

Stephen Covey proposed a time management matrix in 1996, in which he placed important and urgent activities in the first quadrant, important but not urgent tasks in quadrant 2, and, in the last quadrant, activities that are neither important nor urgent, but that by habit the individual performs them and unconsciously steals a large amount of time [2]. "The development of time management is often divided into four generations. In the first generation, what needs to be done (answer the question of what to do) is mainly solved. The second generation adds the question of when it is necessary to do it. The third generation extends the previous two by adding the question of how to perform the task. Finally, the fourth generation focuses mainly on man, self-knowledge and management". The complexity of current times requires the use of information technology in this area of knowledge [3].

Computational intelligence, defined as the technology that allows to exploit computational power to solve "hard" problems, has seen a significant increment in the number of applications within many different fields during the last decades. Undoubtedly, computational intelligence has become a current of thought that has characteristics to help support in the problem of deciding how managers should allocate their time.

Improvements through computational tools help with the reduction of processing times and with optimization [4]. Tools provided by computational intelligence are useful in problems with vital impacts, such as ranging transport models of medical emergency services, prediction of meteorological data to minimize its economic impact, and problems where the result is the recommendations of tourist attractions, for example [4–6].

In most cases, the manager is not able/willing to determine precise proportions of his/her time to perform routine activities. However, the manager may wish to define minimum and maximum acceptable proportions of time. It is also possible that, originating in vagueness or imprecision within the manager's mind, this minimum acceptable value is not well defined and/or the manager does not feel comfortable in expressing it as a precise value. Therefore, a decision support system that exploits computational intelligence to recommend plausible proportions of time to allocate to the diverse manager's activities must be prepared to deal with such situations of uncertainty.

There are several ways to introduce uncertainty into modeling. Fuzzy numbers are a plausible way to model the situation where a number x is not precisely known, but the range where it lies and its distribution are known. This type of numbers is used in many areas, from robotics to finance. In [7] they evaluated the risk associated with investments and in [8] to rank alternatives. There is another way to introduce uncertainty that is potentially simpler than fuzzy numbers, interval numbers. Interval numbers characterize the range where an unknown quantity may be by using uniform distributions. Interval theory allows to determine if a given interval number is greater than or equal to another interval number in a straightforward and intuitive manner [9]. In [10], interval numbers were used to assess risks based on the probability of fails. In [11], a drought risk model is built and evaluated through interval numbers. Solares et al. [12] exploited the ordering properties of interval numbers to characterize and compare investment portfolios. Similarly, Fernandez et al. [13–15] not only characterized investment portfolios through interval numbers, but also the preferences of the investors. Interval numbers are remarkably related to fuzzy numbers [16–18].

Another important issue addressed in this paper is the modelling of preferences. Modelling of preferences has been used in different ways, such as in [19], where a fuzzy technique is applied for order preference and ranking of the alternatives concerning the reverse logistic problem; or by [20] where preference modelling is used to generate individualized interactive narratives based on the preferences of users to improve user satisfaction and experience. One way to model preferences is by using value functions. These types of functions are the result of a very well-studied and well-known theory (see e.g., [21–23]). Recently, value functions have been used to assess project portfolios [24], providers [25], and market segmentations [26], for example. There have been important efforts in creating effective methods to elicit the parameter values of value functions [27–30].

On the other hand, a very effective tool for optimization problems whose decision variables are continuous is differential evolution (DE). This is a tool commonly used for solving engineering problems and it has become very popular among computer scientists and practitioners [31]. Recently, this technique has been introduced in other areas such as finance, marketing, and customer segmentation, as in [15,32].

Regarding the case study of this work, namely the time allocation for managers' activities, some researchers have intended to analyze the impact and importance of this issue, such as in [33], where it is shown how time allocation for sales managers affects the sales team performance. Their findings underscore the importance of effective time management for sales managers across a core set of leader behaviors. Moreover, they argue that when managing more (less) experienced teams, managers should focus on spending more time on managing people (customer interaction). In [34], the influence of entrepreneurs' individual entrepreneurial orientation (IEO) on their time allocation behavior is studied. The findings indicate that proactiveness and risk-taking are associated with specific time allocation behaviors. In [35], it is identified that a core micro-foundation of dynamic managerial capabilities is the ability of the manager to allocate their own time; and it is illustrated that failure to allocate time to capability enactment can lead to capability vulnerability. In [36], it is said that time management practice can facilitate productivity and success, contributing to work effectiveness, maintaining balance, and job satisfaction. Furthermore, the decision support provided to managers must offer flexible recommendations such that the manager can make a final decision according to his/her specific context, but without affecting the approach's effectiveness. In this work, we intend to achieve all these goals.

To the best of our knowledge, there are not published methods that explicitly allocate times to managerial activities. This is likely due to the difficulty for managers to follow strict schedules in ever-changing environments. The problem is, of course, that neglecting the support of recent advances in technology and modeling is discouraged. Traditional approaches to this type of problem consist of mathematical models exploited by exhaustive optimization methods that lead to precise output values where strict schedules are recommended. The manager is not given the option to make a final decision where his/her expert knowledge and that of other managers is used. The recommendation also does not have the flexibility to adapt to unexpected situations. This implies a lack of robustness of traditional approaches. Therefore, in this work, we aim not only to propose a time allocation that best suits the manager (from the perspective of a given objective function), but also to provide sufficient flexibility for the manager to adapt to real-world situations such as considering group decisions and uncertainties. We present a novel way to hybridize some state-of-the-art methods from some theories of the literature (see Section 2)

The paper is structured as follows. In Section 2, we describe the materials and methods used in this work. Section 3 presents the methodology of the proposed approach and details the design of experiments. Section 4 presents and discusses the obtained results. Finally, Section 5 concludes this paper.

2. Materials and Methods

We propose using value functions to model the preferences of the managers (i.e., what the value of each activity is), interval numbers to encompass the uncertainty related to such preferences and to the ideal solution (i.e., on what range the ideal time allocation is), and differential evolution to determine such an ideal solution.

2.1. Value Functions

Value functions [37] can be used to represent the preferences of the managers over a set of decision alternatives regarding time allocation. Value functions are a simple yet effective and very useful way of modeling preferences. This paradigm is particularly relevant here because of the difficulty of defining a mathematical function whose inputs are the times allocated to the activities. It is not straightforward to define tangible impacts on the organizations' objectives for such function. Therefore, the expert opinion of the managers regarding what they consider most convenient is valuable. Value functions are therefore used to represent such opinions by defining "how desirable it is to spend time on a given activity" from the perspective of experts.

The main goal of this type of function is to build a way of relating a real number with each alternative, such that an order on the alternatives can be produced that is consistent with the decision maker's preferences. To achieve it, the theory of value functions assumes the existence of a real-valued function representing the preferences of the decision maker. This function is used to transform the attributes of each alternative into a real number.

2.2. Interval Numbers

An interval number (see [38,39]) represents a numerical quantity whose exact value is not well defined, that is, it is not exactly known. However, it is known that the quantity is within a range of numbers. Let r be a real value lying between r^- and r^+. The interval number representing r is therefore $\boldsymbol{R} = [r^-, r^+]$. A real number s can be represented by an interval number as $[s, s]$. For clarity purposes, we use bold italic font to denote an interval number.

Notice how the nature of the uncertainty modeled by interval numbers is different from that modeled by fuzzy logic. In the former, knowing that the quantity is within a range of numbers is the only known information; in the latter, usually more information about the quantity and range are stated. Therefore, fuzzy logic could handle the proposed approach information in a more sophisticated way than interval theory. However, such sophistication comes at a price, complexity. For example, it is straightforward to determine if an interval number is greater than or equal to another (see function *Poss* below), which usually is not the case for fuzzy numbers. Here we focus on the scenario where the interval numbers are sufficient to model the problem and defer the modeling of such information through fuzzy logic to future research work where the authors are already working.

Basic arithmetic operations that can be performed using interval numbers are addition, subtraction, and multiplication. Let $\boldsymbol{A} = [a^-, a^+]$, $\boldsymbol{B} = [b^-, b^+]$ be two interval numbers. The arithmetic operations between these numbers are defined by:

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

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

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

Evidently, it is not possible to precisely define the order of two interval numbers when there is overlap between them. Thus, a possibility function was defined in [9] to determine the "credibility that one of the interval numbers is at least as great as the another". The possibility function is defined as:

$$Poss(\boldsymbol{A} \geq \boldsymbol{B}) = \begin{cases} 1 & \text{if} \quad p_{AB} > 1, \\ p_{AB} & \text{if} \quad 0 \leq p_{AB} \leq 1, \\ 0 & \text{if} \quad p_{AB} < 0 \end{cases}$$

where $p_{AB} = \frac{a^+ - b^-}{(a^+ - a^-) + (b^+ - b^-)}$.

When $a^+ = a^- = a$ and $b^+ = b^- = b$, $P(\boldsymbol{A} \geq \boldsymbol{B}) = \begin{cases} 1 \text{ if } a \geq b, \\ 0 \text{ otherwise}. \end{cases}$

In [13,14], the value $Poss(\boldsymbol{A} \geq \boldsymbol{B})$ is interpreted as "the credibility of a being greater than or equal to b, where a and b are two *realizations* from $\boldsymbol{A}$ and $\boldsymbol{B}$", where a *realization* is a given real number within the interval number.

2.3. Differential Evolution

Differential evolution [40] is an optimization tool highly effective and efficient when addressing optimization problems whose decision variables are continuous. It is characterized by approximating the optimal solution by improving multiple possible solutions at the same time. Differential evolution (DE) is especially convenient when the optimization problem does not satisfy the requirements of exhaustive mathematical optimization methods. However, it does not ensure to find the overall best solution, but only suboptimal solutions. The found solutions are generally good enough to be accepted by the user.

DE uses a generational improvement that simulates biological evolution. At any given moment it deals with a set of potential solutions called individuals or agents; the set of individuals is called population. The parameters used by DE consist of a crossover probability, $CR \in [0, 1]$, a differential weight, $F \in [0, 2]$, and a number of individuals in the population, $P_{size} \geq 4$. Each individual in the population is represented by a real-valued vector $z = [z_1, z_2, \ldots, z_m]^{\mathrm{T}}$, where z_i is the value assigned to the ith decision variable and m is the number of decision variables.

Let $y \in \mathbb{R}^m$ be a temporary solution. DE must perform the following steps:

1. Initialize individuals placing them in a random position within the search space. This means that a random value must be assigned to each decision variable respecting the constraints associated with the variable.
2. Perform the following steps until a termination criterion is reached. This criterion is defined here as a number of iterations, $N_{iterations}$.
    a. Perform the following steps for each individual z in the population
        i. Let a, b, c be individuals from the population chosen randomly such that z, a, b, c are all different.
        ii. Randomly define $r \in \{1, \ldots, m\}$
        iii. Perform the following steps for each $i \in \{1, \ldots, m\}$
            1. Randomly define $u \in [0, 1]$.
            2. If $u < CR$ or $i = r$, set $y_i = a_i + F(b_i - c_i)$, otherwise set $y_i = z_i$.
        iv. If $f(z) \leq f(y)$, then replace z for y in the population. $f(\cdot)$ is a given fitness function (see Equation (1) below).
3. Select the individual z of the population with the best performance $f(z)$.

3. Methodology

Assume the existence of a set of activities, $A = \{a_1, a_2, \ldots, a_n\}$, relevant for the manager of a given company. Let x_i denote the proportion of time allocated to $a_i \in A$; $\sum_{i=1}^{n} x_i = 1$ and $x_i = t_i/T$, where t_i is the time assigned to a_i and T is the total time that the manager assigns to the activities in A. An approach based on computational intelligence that is focused on determining the precise value of x_i is unrealistic since day-to-day operations and urgent issues may alter scheduled activities; moreover, the manager may not feel comfortable with the advised values of x_i. However, such unprevented operations and issues usually imply significant deviations from the ideal allocation of the manager's time. Therefore, we describe here a hybrid approach based on computational intelligence and multicriteria decision aid that exploits interval theory to propose a flexible allocation of the manager's time.

The idea is to provide the manager with the flexibility to choose, among a set of plausible values of x_i, the most convenient one according to his/her specific context and preferences. Let $\boldsymbol{x}_i = [x_i^-, x_i^+]$ denote an interval number representing the set of plausible values from which the manager can choose what he/she considers the most convenient one.

In order to define a plausible set of values of x_i, we perform an elicitation of preferences based on multicriteria decision aid that ensures the maximization of the manager's preferences.

The proposed approach consists of four main stages:

1. Determine the set of activities in A.
2. Assign a relative value v_i to each $a_i \in$ A; this value represents "how desirable it is to spend time on activity a_i".
3. Determine the set of constraints imposed to the time allocation.
4. Optimize the total value of the performed activities by defining $x_i,\ i = 1, \dots, n$.

3.1. Determining the Set of Activities in A

On a preliminary survey of both expert opinions and literature, we found out that activities commonly performed by managers can be assigned to, at least, the following classes:

- Supplier Management
- Marketing and Sales Management
- Strategic Planning
- General administration (Internal processes)
- Inventory Management
- Financial Capital Management (Cash Flow)
- Strategy Management
- Quality and Service Management
- Human Capital Management

Evidently, the specific context of the manager would determine if a different set of activities is considered during the decision-making process. Therefore, a particular analysis of the context handled should be carried out.

3.2. Assigning a Relative Value v_i to Each $a_i \in A$

During this stage, a value representing "how desirable it is to spend time on activity a_i" is defined relatively to the values assigned to the rest of activities in A. Different techniques can be followed to determine such values (cf. [41,42]). The chosen technique must define cardinal values as opposed to ordinal ones that some elicitation procedures define (e.g., [43]). A plausible way to assign such values is then through an elicitation procedure, such as the Swing method [27,28], where the preferences of the manager (or a group of managers from the same sector, region or expertise) are properly defined. If a group of managers is consulted to define the value of the *i*th activity, then multiple values will be surely determined. To deal with this imprecision, the value of the activity can be defined as an interval number $v_i = [v_i^-, v_i^+]$ where v_i^- and v_i^+ are the minimum and maximum values assigned to the *i*th activity by the group of managers.

3.3. Determining the Set of Constraints Imposed to the Time Allocation

Common constraints considered when scheduling the time of managers are:

- avoid spending too little time on some activities
- avoid spending too much time on some activities
- avoid spending too much time on all the considered activities
- avoid spending too little time on all the considered activities
- address a maximum number of activities
- address at least a certain number of activities

The previous constraints can be formalized, respectively, as follows:

$$x_i \geq l_i y_i$$

$$\boldsymbol{x}_i \leq \boldsymbol{u}_i y_i$$

$$\sum_{i=1}^{n} x_i \leq \boldsymbol{U}$$

$$\sum_{i=1}^{n} x_i \geq \boldsymbol{L}$$

$$\sum_{i=1}^{n} y_i \leq N^+$$

$$\sum_{i=1}^{n} y_i \geq N^-$$

$$y_i = \{0, 1\}$$

where $\boldsymbol{l}_i$ and $\boldsymbol{u}_i$ are the lowest and highest proportions of time that the manager is willing to allocate to ith activity. $\boldsymbol{L}$ and $\boldsymbol{U}$ are the lowest and highest proportions of time that the manager is willing to allocate to all the considered activities. N^- and N^+ are the minimum and maximum number of activities to which the manager allocates some of his/her time. Additionally, $y_i = 1$ if the manager allocates some time to the ith activity and $y_i = 0$ otherwise. Note how $\boldsymbol{l}_i$, $\boldsymbol{u}_i$, $\boldsymbol{L}$, and $\boldsymbol{U}$ are all defined as interval numbers, providing the manager with additional flexibility when defining the optimization model.

3.4. Defining an Objective Function

Let $X = (\boldsymbol{x}_1, \boldsymbol{x}_2, \ldots, \boldsymbol{x}_n)$ and $V = (\boldsymbol{v}_1, \boldsymbol{v}_2, \ldots, \boldsymbol{v}_n)$ be the sequences of time proportions and activity values, respectively; and let $f(X, V)$ be a function that determines the total value of the time allocation made by the manager. Then, solving the following general statement implies finding the best time allocation:

$$\underset{\boldsymbol{x}_1, \boldsymbol{x}_2, \ldots, \boldsymbol{x}_n}{\text{maximize}} f(X, V) \tag{1}$$

Subject to

$$\boldsymbol{x}_i \geq \boldsymbol{l}_i y_i$$

$$\sum_{i=1}^{n} x_i \leq \boldsymbol{U}$$

$$\sum_{i=1}^{n} x_i \geq \boldsymbol{L}$$

$$\sum_{i=1}^{n} y_i \leq N^+$$

$$\sum_{i=1}^{n} y_i \geq N^-$$

$$y_i = \{0, 1\}$$

We propose to define $f(X, V)$ as a weighted sum, that is:

$$f(X, V) = \sum_{i=1}^{n} \boldsymbol{v}_i \boldsymbol{x}_i$$

We also propose to use differential evolution to address Equation (1).

3.5. Optimizing the Total Value of the Performed Activities

Multiple alternative techniques can be used to optimize Equation (1). However, given the interval-based feature of such equation (necessary in the approach to provide the required flexibility) and its definition as an NP-problem (cf. [44]), a metaheuristic optimization technique should be used. Metaheuristics are optimization techniques of the area of computational intelligence that have shown to be reliable when addressing hard problems and that can be flexible to adapt to situations as the stated above. It has been proved that differential evolution (DE) (e.g., [45]), a highly efficient metaheuristic, often outperforms other optimization techniques when addressing problems similar to that stated in previous sections; particularly, when the optimization problem is mono-objective and with real-valued decision variables. Therefore, we use here differential evolution to define the most convenient values associated to the manager's activities.

3.6. Experimental Design

To assess the proposed approach, we have applied the methodology to a set of nine micro, small and medium-sized organizations in the commerce sector. Each of the five steps in the methodology described above was applied to the organizations, creating a single case study.

The application of the proposal to this case study is twofold. On the one hand, it will allow us to show how the proposed approach can work with a group of decision makers, and how each of them can take advantage of the other decision makers' expert knowledge. On the other hand, the assessment will shed light on the performance of the proposed approach, and we will be able to determine how the proposed approach's recommendations satisfied each manager's preferences. The performance of the proposed approach, assessed through the satisfaction level of each manager, is compared to the performance of a benchmark.

4. Results and Discussions

This section provides (i) the general recommendations provided to the managers in the case study, and (ii) a comparison of each manager's satisfaction between the recommendations provided by the proposed approach and an approach from the literature.

4.1. Results Obtained by the Proposed Approach

The results of the first stage of the methodology described in the previous section showed that the managers in the case study determined the following activities as the ones that should be prioritized when allocating resources:

1. Supplier Management
2. Marketing and Sales Management
3. Strategic Planning
4. General Administration (internal processes)
5. Inventory Management
6. Financial Capital Management (cash flow)
7. Strategy Management
8. Quality and Service Management
9. Human Resource Management

A wide description of these activities is presented in Appendix A.

Regarding stage two of the methodology, we used the so-called Swing method to elicit from the managers the values in the additive value function denoted by Equation (1) (See [27,46], to see a more in-depth description of the method). The results obtained are shown in Table 1.

Table 1. Values assigned by the managers to the activities regarding "how desirable it is to spend time on activity a_i"

Activity	Manager 1	Manager 2	Manager 3	Manager 4	Manager 5	Manager 6	Manager 7	Manager 8	Manager 9
Supplier Management	7%	22%	0%	9%	0%	5%	13%	11%	13%
Marketing and Sales Management	23%	2%	10%	14%	21%	5%	12%	19%	19%
Strategic Planning	10%	18%	32%	1%	19%	53%	14%	11%	9%
General administration (internal processes)	3%	16%	6%	29%	0%	5%	13%	21%	11%
Inventory Management	7%	9%	3%	3%	0%	5%	13%	17%	10%
Financial Capital Management (cash flow)	14%	7%	26%	3%	0%	11%	14%	14%	11%
Strategy Management	16%	2%	10%	3%	20%	11%	13%	0%	9%
Quality and Service Management	10%	11%	10%	19%	20%	3%	7%	0%	9%
Human Resource Management	10%	13%	3%	19%	20%	3%	0%	7%	11%

After defining the weights that each manager assigned to the activities regarding "how desirable it is to spend time on activity a_i", we intend to embrace the whole set of preferences by defining a unique interval number for each activity whose boundaries are set by the minimum and maximum weights provided by the managers, as shown in Table 2. The goal of this aggregation of the managers' preferences is to deal with the whole set of organizations (with similar characteristics in very similar contexts) as a single case study; thus, implying that the combined experience of the managers is convenient to dictate how the organizations' managers should allocate their times.

Table 2. Values assigned by the managers to the activities.

Activity	Minimum Value (%)	Maximum Value (%)
Supplier Management	5	22
Marketing and Sales Management	2	23
Strategic Planning	1	53
General administration (internal processes)	3	29
Inventory Management	3	17
Financial Capital Management (cash flow)	3	26
Strategy Management	2	20
Quality and Service Management	3	20
Human Resource Management	3	20

Stage three of the methodology in Section 3 requires determining the constraints that the managers want to impose to the problem in Equation (1). For the case study carried out here, we found that the managers are only interested in defining boundaries to the proportion of times allocated to the activities. This is originated in the idea none of the nine fundamental activities mentioned above should be performed during very short or very long periods of time. The constraints established by the managers are shown in Table 3.

Table 3. Lowest and highest proportions of time allowed per activity.

Activity	Lowest Proportion (%)	Highest Proportion (%)
Supplier Management	2	25
Marketing and Sales Management	4	8
Strategic Planning	8	17
General administration (internal processes)	4	21
Inventory Management	2	8
Financial Capital Management (cash flow)	4	12
Strategy Management	4	8
Quality and Service Management	8	25
Human Resource Management	12	25

Finally, an effective optimization tool based on metaheuristics, differential evolution, was used to determine the best allocation of times. Common parameter values were assigned to this optimizer. The crossover probability, *CR*, was set to 0.9; the differential weight, *F*, was set to 0.8; the population size, P_{size}, was set to 200; and the number of iterations, $N_{iterations}$, was set to 100. Table 4 shows the results obtained when exploiting the proposed approach regarding the case study

Table 4. Recommendations of the system. If the manager spends a proportion of time indicated by the corresponding interval on a given activity, the manager would be maximizing the total value of the time allocation.

Activity	Best Time Recommended (%)
Supplier Management	[12, 21]
Marketing and Sales Management	[4, 6]
Strategic Planning	[10, 13]
General administration (internal processes)	[15, 18]
Inventory Management	[6, 7]
Financial Capital Management (cash flow)	[4, 9]
Strategy Management	[6, 7]
Quality and Service Management	[19, 25]
Human Resource Management	[15, 17]

As can be seen from Table 4, the summatory of lowest values is lower than 100%, that is, $\sum v_i^- < 100$. Similarly, the summatory of highest values is greater than 100%, that is, $\sum v_i^+ > 100$. This is a desirable feature of the proposed approach regarding pragmatism. When exploiting a decision support system, it is convenient for the manager to have a sufficiently flexible recommendation to generate the final decision. Furthermore, such final decision still must ensure robustness. Through recommendations provided in the form of ranges, where 100% of the time dedicated by the manager to the activities is within the recommended boundaries, the proposed approach satisfies both requirements allowing the manager to decide the precise times dedicated to the activities.

4.2. Comparison with a Benchmark Approach

Once the proposed approach outputted general recommendations for the group of managers (Table 4), the recommendations and the individual preferences stated in Table 1 are used to create a "satisfaction level" per manager by exploiting Equation (1). Such satisfaction level is compared to that obtained by an optimizer from the literature addressing a simplified version of the problem. (Note that there are not published methods that can address the whole complexity of the problem stated in Section 4 in a straightforward manner, so we built a simplified version of the problem so it could be addressed by methods from the literature whose results could be used as a benchmark.) The simplified version of the problem is defined as follows.

Since, it can be shown that, for any interval numbers $\boldsymbol{E}$ and $\boldsymbol{D}$, if e and d are, respectively, the middle points of $\boldsymbol{E}$ and $\boldsymbol{D}$, then $\boldsymbol{E} > \boldsymbol{D} \Leftrightarrow e > d$ and $\boldsymbol{D} = \boldsymbol{E} \Leftrightarrow d = e$ (dictatorship of the middle point), we redefine the problem in the case study so now the values "assigned" by the managers to the activities correspond to the middle points of those actually provided by the managers and shown in Table 2. Such values must be normalized. The new values are shown in Table 5.

Table 5. Simplification of the values assigned by the managers to the activities. The middle points of the original intervals have been normalized.

Activity	Value (%)
Supplier Management	11
Marketing and Sales Management	10
Strategic Planning	21
General administration (internal processes)	13
Inventory Management	8
Financial Capital Management (cash flow)	11
Strategy Management	8
Quality and Service Management	9
Human Resource Management	9

The original set of activities and constraints are maintained to ensure fairness. The objective function and the decision variables are now precise; that is, they are real-valued.

Applying the Simplex method to this simplified version of the problem provides the recommendations shown in Table 6.

Table 6. Best solution found by a benchmark approach to a simplified version of the problem.

Activity	Best Time Recommended (%)
Supplier Management	25
Marketing and Sales Management	4
Strategic Planning	17
General administration (internal processes)	21
Inventory Management	2
Financial Capital Management (cash flow)	7
Strategy Management	4
Quality and Service Management	8
Human Resource Management	12

We now compare the satisfaction level of each manager produced by the recommendations in Tables 4 and 6. This comparison will shed light on the performance of the proposed approach to encompass and exploit the expert knowledge of a group of decision makers from the perspective of each manager. With this purpose, the value function in Equation (1) is used to aggregate the value assigned by each manager in Table 1 with the recommendations of Table 4 first (to create the satisfaction level produced by the proposed approach), and with the recommendations of Table 6 later (to create the satisfaction level produced by the benchmark approach). Such satisfaction levels are shown in Table 7 (note that, since the recommendations provided by the proposed approach consist of interval numbers, the satisfaction levels are given also as interval numbers).

Table 7. Satisfaction level of each manager regarding the recommendations provided by the benchmark and proposed approaches.

Manager	Benchmark	Proposal
1	8.76	[8.55, 11.76]
2	15.19	[11.9, 16.32]
3	10.54	[8.67, 12.1]
4	12.26	[13.03, 16.75]
5	8.87	[10.74, 13.53]
6	13.42	[9.27, 12.51]
7	11.16	[8.84, 12.44]
8	11.95	[8.96, 12.3]
9	11.22	[9.81, 13.46]

From Table 7, we can see that each satisfaction level provided by the benchmark approach is contained within the corresponding satisfaction level provided by the proposed approach (except for Managers 4 and 6). This means that the recommendations of the proposed approach combined with good final decisions by the manager could imply better satisfaction levels for him/her. Of course, this combination could also imply worse satisfaction levels. So, here is where the synergy between the expert knowledge of each manager and the advances in computational intelligence and decision support systems can take place. The proposed approach exploits the experience of the group through computational intelligence and gives the opportunity for each manager to provide a final decision where his/her particular knowledge and preferences could lead to better results.

Finally, note how the simplified version of the problem is unrealistic. The managers would never be satisfied following recommendations of strict schedules; so, an approach that depends on the managers following such schedules would lack pragmatism.

Since the paper's goal is to present a novel approach to deal with the realistic problem through the exploitation of a computational intelligence-based system for the first time, it is out of the scope of this work to perform in situ experiments to capture indicators of the organizations.

5. Conclusions

This work presents a novel idea to allocate the times of managers to their main activities. The idea exploits the so-called computational intelligence within a decision support system that provides recommendations about how managers should allocate their times.

Even when computational intelligence has been widely exploited in a plethora of fields, to the best of our knowledge, it has never been applied to the problem of supporting organization managers to allocate their times. We believe this is due to the "hardness" often imposed to models that would represent this problem. That is, models based on computational intelligence usually provide strict recommendations that would not allow the manager to deviate from such recommendations with robustness of effectivity. This is not ideal since managers usually make decisions on the progress of the activities. Therefore, here, a novel hybrid approach that integrates value function theory, interval theory and evolutionary algorithms, intends to give the manager flexibility regarding the times that he/she should dedicate to his/her activities. Furthermore, we ensure that the effectiveness of the approach is maintained as long as the actual allocated times remain within the recommended slack.

The proposed approach was applied in a case study to the managers of nine micro, small and medium-size organizations that participated during the whole process of the methodology described in Section 3. Tables 1–3 show the information provided by the managers that worked as inputs to our approach. Table 4 provides the results obtained. Such results proved to fulfill the constraints imposed by the managers and to maximize the total value of time allocated to the activities from the perspective of group decision. Tables 5–7 show a comparison between the results of our approach and those of a method from the literature. Since the benchmark method is not able to deal with the whole complexity of the case study's problem, a simplified version of the problem was created. The results of both approaches are assessed from the perspective of each manager within the group. The comparison shed light on how the proposed approach could provide a higher satisfaction level to the managers if they make a convenient final decision. Therefore, we conclude that the proposed approach could be of pragmatical relevance to support the decisions of the managers; at least of those in charge of micro-, small- and medium-sized organizations.

Future research lines include (i) provide more in-depth analysis of the approach's impact by assessing the organizations' performances before and after implanting the approach; (ii) use more sophisticated techniques to model the manager's preferences, for example, exploiting the so-called outranking approach (see [47]) and Fuzzy Logic [48]; (iii) follow a statistical procedure to define the parameter values of the approach.

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Appendix A. Complete Descriptions of the Activities Selected by the Managers

Appendix A.1. Supplier Management

The certainty that a trading company has that its products will be sold are based on the conditions negotiated with its suppliers, which include:

- **The Purchase Price**: Obtaining the best purchase price in the market guarantees the trading company that its sales price will not only be competitive, but also will get the widest Margin on sales, giving them a competitive advantage. If eventually there is a need for a price reduction, this can be done more easily than its competition.

- **The Selling Margin**: By obtaining the best purchase price, the best selling margin is obtained.

- **Credit**: Obtaining the longest credit term provides room for maneuver if the trading company grants the necessary credentials required by the market.

- **Quality**: The trading company must review and confirm that the supplier has implemented qualities systems that guarantees that it complies with the technical specifications of the product offered, guarantee supply, and meets delivery times by reviewing its sources of supply or at least an investigation that shows that the raw materials used are available in time and form in the market.

- **Supply**: This means that the supplier must have the capacity to supply the quantities required by the trading company promptly to avoid the damage caused by losing the sale due to shortages in the customer's inventory.

- **Warranty and Service**: The supplier must offer immediate response to customer claims for defects in the product, the replacement of the same, and bear all costs of handling and freight in the process of return and replacement of products.

- **Marketing**: Nowadays, all suppliers, manufacturers, and distributors have in their budget a sufficient amount to support their customers with financial resources, and in-kind for marketing actions, since these represent the indispensable distribution channel to move their products making them reach the final consumer.

The money support can go from the rent of spaces, for exhibition, or preferential positions, payment of advertising, exclusivity, etc., in-kind can be with promoters personnel to restock the sales floor with merchandise, demonstration-saleswomen to move the merchandise, POP material, exhibitors, promotional campaigns, and others.

- **Strategic Alliances**: This is the highest level that can be reached in the relationship with suppliers, it is reached when the purchase volumes of the commercial company represent an important percentage of the supplier's sales in such a way that if the supplier were to lose the client, this would cause disruptions in its operation that would eventually translate into losses.

The benefits of an alliance for the commercial company includes: preferential prices, guaranteed supply, free replacement of merchandise, promotional and advertising support, cashing-kind payments, prizes and incentives, exclusivity in product lines, and market territories, etc. They are frequently formalized with the signing of the corresponding contracts, which are renewable from time to time.

Appendix A.2. Marketing and Sales Management

- **Sales Management**: The sales generate the income of the commercial enterprise, the security to a great extent that these are given, has its origin in the quality of the negotiation with suppliers, but the other part is complemented with a deep knowledge of the product, the market, and the competition. Among the most important points that the general manager must attend to are the following:

- **In-Depth Knowledge of the Wants and Needs of His Customers**: There are multiple software tools known as CRM (Customer Relationship Management) that provide all the information regarding the tastes, needs, frequency, and buying habits of the customers in addition to providing complementary valuable and personal information about them such as, names, birth dates, anniversaries, number, and ages of children, etc., which facilitates the company to have personal and close communication with its customers.

- **Sales Force**: To create, develop, and maintain the quantity and quality of elements necessary for the generation of sales is a fundamental task of the general manager, whether it is a linear or pyramidal structure, on-site or virtual, must maintain permanent attention to the performance of each and every one of its members, always taking care, not only to cover the established objectives but also to meet the needs expressed by its members, through adequate dynamic retribution of performance that includes the granting of incentives to maintain high motivation and satisfaction for their work.

The permanent training in the sales technique, the method and work plan whose objective is the increasing attention of prospects and the coverage of the sales quota must be permanently attended by the General Manager.

- **Marketing**: The general manager must know and define the customer and consumer profile, what it is like, where is located, where it moves, what places frequents, what is it socioeconomic level, this leads to identifying the target market and to quantify potential market with which will be able to implement.

- **The Communication Plan**: The target market must know the existence of the commercial company, its products, offer, and service it provides. The quantity, quality, frequency, and intensity of the messages received by the target market will largely determine the level of response to the offer provided by the commercial company, which is translated into: traffic of potential customers (prospects) to the company's sales floor, phone calls, emails, and other digital media, requesting information and quotations, increasing acceptance of visits from the company's salesperson, increase in orders and consequently higher sales.

The implementation of a CRM in the company is of great help for the success of the communication plan.

- **Media Plan**: The selection of the media to be used for communication is very important, so the general manager must apply himself to investigate which are the ones that have a greater impact on the target market depending on the objective of the communication, which may be to provoke immediate sales, increase traffic on the sales floor, fix the commercial brand in the customer's mind, create loyalty, etc.

Traditional media; press, radio, television, billboards, specialized magazines, flyers, direct mail, tabloids.

Digital Media; websites, social networks, web search engines, influencers, sales chats, and others.

- **Competitor Analysis**: Daily monitoring of the competition will allow the general manager to know promptly the commercial and promotional actions which will allow him to react adequately to avoid the loss of customers and eventually anticipate better actions, counteracting its main competitors.

- **The Selling Price**: The determination of the selling price is fundamental for the commercial company as it fixes its competitive position in the market since it can be a low price, equal to or higher than the competition, it impacts directly on the volume of sales and the most important part, it contributes to the gross profit margin that must be sufficient to cover its operating expenses and provide the profit desired by the company.

Appendix A.3. Strategic Planning

The company define well its goals, its aspirations, and how far it wants to go in the medium–long term. It is up to the general manager to visualize the scope, coverage, growth, the position it wishes to have in the market, and the time frame in which it wishes to achieve it.

Setting the direction, determining the objectives, formulating the strategies, allocating the resources, executing the action plan, and inspiring the team is the role of the general manager.

Appendix A.4. General Management

In the broadest sense, the general manager applies the administrative process of planning, organization, direction, and control in all areas of the company implicit in the value chain in what Michael Porter defines as primary activities and costs, as well as the support activities and their costs. The common thread is represented by its internal processes, which must be formulated in a clear, complete, and updated manner at all times.

- **The Value Chain**: Every commercial enterprise shares the same value chain, starting in the suppliers' market for the purchase and supply of the goods to be sold, the transportation of the products to the company's warehouses and the inherent logistics, the safekeeping, rotation, and, if necessary, the movement to the sales floor for display, sale, invoicing and collection, packaging, physical delivery to the sales floor or home delivery and the corresponding logistics, to conclude with warranty support and after-sales service.

In the whole chain, there are several activities that the general manager must be personally involved in, some of them being executed in their totality and permanently, that is to say, they cannot be delegated, for example, the negotiation with the suppliers, while some roles can be delegated, he cannot stop being personally involved.

In each of the processes derived from these activities, the general manager must be involved by executing, delegating, or supervising their correct and timely application.

Appendix A.5. Inventory Management

The commercial enterprise must deliver to the customer a quality product, the product must be at the beginning of its life period, whether it is of short duration such as perishables or long life such as furniture, machinery, and capital goods.

Some long-life products, however, only have a short period of time to be sold, as in the case of fashion items or those that are replaced by the next year's model, as in the case of automobiles.

Long stays in warehouses or on the sales floor makes them obsolete and discontinued, in addition to the natural deterioration due to the passage of time.

The constant review of rotation, proper management of inventories, and their replenishment to maintain adequate levels and avoid shortages that cause loss of sales is an obligatory function of the general manager.

Appendix A.6. Financial Capital Management (Cash Flow)

The company must have at all times the availability of financial resources to meet its operating needs, the timely payment even in advance to suppliers, the emergency purchase of assets such as the replacement of computer equipment or the repair of transportation equipment, the payment of taxes, personnel settlements and similar require having the liquid capital on hand to cover any requirement; therefore, the planning, collection, application, and control of resources is a daily task of the general manager.

- **Operating Expenses**: These are disbursements intended to keep the company in operation; they enable the various activities and daily operations to be carried out, without which it would not be possible to achieve the company's objectives.

The expense is necessary and unavoidable and the resources necessary for this purpose come from the margin provided by sales, so the higher the expense, the lower the margin, hence the importance of maintaining strict control and vigilance in the amount and destination of the expense.

Appendix A.7. Strategy Management

The strategy is how the company decides to compete in the market, it represents the specific actions it takes to serve the market, face the competition, and offer greater value to the customer.

How is it going to differentiate itself from the competition, how is it going to make the market perceive greater value when selecting its offer, how is it going to obtain a competitive advantage?

The strategy for a company as such does not exist, it is created, it is the result of the creativity, ingenuity, knowledge, and experience of the general manager who many times is the same entrepreneur. Of course, many managers decide to imitate the actions of the market leaders, but that makes them followers, places them always behind the competition, and generally in last place.

The planning, design, and implementation of the strategy is a very personal function of the general manager.

Appendix A.8. Quality and Service Management

Delivering quality products implies impeccable execution in every process along the value chain. It is the general manager's role to ensure that he and his team of collaborators carry out the assigned activities promptly. Planning, process implementation, resource allocation, and close supervision is the task of the general manager.

Appendix A.9. Human Capital Management

The company is its people, the customer deals with people who represent the company and are responsible for fulfilling the company's promise to the customer by exceeding their expectations.

This is only possible if the team of collaborators is kept at a high level of motivation, committed, and willing to provide solutions.

The primary need is the perception of adequate and sufficient remuneration, but it is not the only one, it also seeks to satisfy the needs of professional development, belonging to a team, recognition, and security of permanence, and growth in the company, among others.

The general manager must create working conditions that meet the expectations of all employees, motivate them, inspire them, and focus on the vision.

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