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Enhancing Member Satisfaction and Resource Utilization: An Integer Programming Model for Summer Subsidy Allocation

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Abstract. This study addresses the challenge of optimizing summer subsidy allocation for foundation members under multiple constraints. We develop an integer programming model to manage this process, incorporating various beneficiary selection criteria and operational constraints. The model was applied to real data from a Moroccan foundation for the 2021-2023 camping seasons. Results demonstrate 100% assignment and filling rates across all member categories, with execution times ranging from 8.17 to 251.17 seconds. This approach offers a flexible, efficient solution for managing social benefits, allowing members freedom in choosing camping locations and dates while maximizing resource utilization. The model's successful implementation provides insights into optimizing resource allocation in social benefit systems.

Keywords: Summer Subsidy Allocation, Resource Utilization, Decision-Making, Assignment Problem, Operational Research, Integer Programming, Social Benefit Management.

1. Introduction

The rapid evolution of artificial intelligence and operational research methods is significantly altering the landscape of resource management in social, economic and manufacturing sectors (Beresnev *et al.*, 2020) (Mohamud *et al,*. 2024) (Marwa *et al.*, 2025). Operational research techniques are extensively used to model and solve real-world problems encountered in complex organizational tasks and resource allocation processes (Pham *et al.*, 2020) (Laengle *et al.*, 2017) (Gao and Cui, 2021), and it provides powerful tools to solve it such as integer programming techniques (Pathumnakul *et al.*, 2006) (Xiao *et al.*, 2020), in fact, (Argyris *et al.*, 2022) explores the challenge of resource allocation among multiple beneficiaries, focusing on the balance between efficiency and fairness. They introduce a new method that maximizes efficiency while ensuring fairness through specific constraints. In the same context, (Ordu *et al.*, 2021) developed a model linking all hospital services and specialties, including A&E, outpatient, and inpatient services. It forecasts demand, captures patient pathway uncertainties using discrete event simulation, and estimates required bed capacity and staff needs through a linear optimization model for a mid-size hospital in England. Always around resource allocation problem, (Li *et al.*, 2020) presents an optimization model for allocating agricultural water and land resources under uncertainty. It integrates intuitionistic fuzzy numbers, mixed-integer non-linear programming, and multi-objective programming.

Integer programming (IP) is a powerful operational research technique commonly used to formulate decision-making problems encountered in various disciplines (Neira *et al.*, 2020) *(Soufyane et al, 2024).* Its versatility stems from its ability to handle complex optimization problems with integer-valued decision variables (Qin *et al.*, 2020) (Sauletekio *et al.*, 2025). This makes IP a valuable tool across a wide spectrum of fields, including business and finance (Babat, *et al.*, 2018) (Benita *et al.*, 2019), engineering and design (Luo *et al.*, 2023) (Daskalaki *et al.*, 2004)), healthcare (Pardede *et al.*, 2019) (Zanda *et al.*, 2018) and education (Majdoub *et al.*, 2024). Within Integer programming, a specific type called the assignment problem tackles tasks of allocating resources to entities (Faudzi *et al.*, 2018), typically with the goal of minimizing cost or maximizing efficiency. These problems are frequently encountered in resource allocation scenarios (Salari *et al.*, 2020) (Soufyane *et al,* 2023). For instance, (Saddoune *et al.*, 2012) combined column generation and dynamic constraint aggregation to solve a crew pairing and assignment problem. And (Lian *et al.*, 2018) propose a novel and flexible class of algorithms for the assignment problem, utilizing order weighted averages (OWAs), a parameterized class of mean aggregators designed specifically for resource allocation tasks.

While these studies demonstrate the applicability of integer programming and assignment problem to various allocation problems, they do not address the specific constraints and objectives involved in summer subsidy allocation for foundation members. Our study extends this work by developing a tailored model for this context. By leveraging the strengths of integer programming, particularly the constrained assignment problem, we propose a decision-making solution that effectively addresses the unique challenges of resource allocation in summer subsidies management. Our model tailors these techniques to the specific context of summer subsidy allocation for foundation members, by incorporating constraints and objectives relevant to this problem, such as benefiting rules and resource limitations. This solution bridges the gap between optimization techniques and summer subsidy allocation for foundation members which allow for an efficient and optimal solution that balances member satisfaction with resource utilization.

The ancient management system of the camping service provided by the Moroccan Mohammedia Foundation for Social Works of Judges (MFSWJ) to its members relied entirely on its affiliated camping centers, and it used the booking stays management system to handle this service in its affiliated centers (Majdoub *et al.*, 2021). The current system for managing camping stays is characterized by several specific features. The camping periods are restricted to a fixed list determined by the foundation, limiting the flexibility for members. Additionally, the number of foundation centers is capped at seven, which may constrain availability and options for the members. Each member is required to specify the camping time, center, and residence type in their request, which must align with the predetermined options. The booking system currently in place follows a weekly approach to assign residences to members. These features present some negative implications on the management of the camping service, mainly: The members find themselves constrained by the fixed camping periods and camping location options, also each member have a low possibility of benefiting because of the congestion of some members on certain camping locations at the same periods. Furthermore, these centers may become unavailable for camping due to various factors, including local development projects, pandemics... At this level, the foundation aims at improving the management strategy of the camping service provided to its members, through using new ideas and resources that perform the quality of the camping service management. The foundation proposes offering summer subsidies as an alternative benefit, though due to high costs, only a limited number of members can receive these subsidies. Hence, the process of selecting beneficiaries becomes a very difficult task for the foundation directorate.

The objective in this work is to build a new decision support system to deal with this issue. Thus, we propose a new decision-making solution to manage the operation of selecting beneficiaries autonomously taking into account new rules and requirements. The main advantage of the new solution is that the new model treats the problematic seasonally and not weekly, moreover, the new strategy takes the choice of the camping time and the camping location to the member himself. Using integer programming and heuristic, the new solution is treated as a constrained assignment problem, with constraint sets representing the rules to be respected.

The following sections of this paper delve deeper into our proposed approach for summer subsidy allocation. Section two focuses on the problem context within the Mohammedia foundation of justice. Here, we'll explore the current beneficiary selection process, its limitations, and any relevant rules established by the foundation directorate. Section three dives into the mathematical formulation of our solution. This section will detail the sets of notations, decision variables, the objective function we aim to optimize, and the constraint sets that ensure the solution adheres to the rules and limitations outlined in section two. Next, section four puts our model to the test. We'll describe how we utilized real data from the Mohammedia foundation for the years 2021, 2022, and 2023 to validate our approach. The results of applying the model to this real-world data will be presented and compared to the current allocation process or any existing benchmarks. Finally, section five concludes the paper by summarizing our key findings and discussing the significance of the proposed model for summer subsidy allocation within the foundation. We'll also outline potential areas for future research or improvements to further refine our solution.

2. Literature Review

The problem of managing camping service has been introduced in (*Majdoub et al.*, *2021*), it is a resources management problem that consists to select, between all candidates, beneficiaries of the camping service offered by the foundation. In fact, this camping service allows members to benefit from the booking stays at foundation residences to spend the summer holiday with their families, during every week of the summer season, each foundation member requests for benefiting from the camping service, the problem consists to select members having such criteria to benefit from the camping service, this selection is made under several constraints ensure consistency of the model and equity among members. The complexity of the problem lies in the number of residences that is almost negligible in comparison with the number of candidates, moreover, constraints of the model make the problem NP-hard and unsolvable using traditional techniques (*Majdoub et al., 2021*) *(Soufyane et al., 2024)* .

The key idea behind this independent solution has been appeared during the Corona virus pandemic, in fact, this pandemic was the essential factor that was perturbed the management processes of the booking stays at summer centers of the foundation. It necessitated the cancellation of camping services at foundation centers to prevent gatherings and limit virus spread. At this level, the old system proposed by *(Majdoub and Loqman, 2021)* has become unusual during this special case. Thus, the foundation direction decided to ban camping in their centers in order to prevent the spread of the Corona virus, to keep the benefit operation from the camping service available to their members, and to look for a new solution that guarantee continuity of the camping service during emergencies and special cases.

This new solution consists to provide foundation members an alternative way to benefit from the camping service. The foundation makes available to their members a limited number of summer subsidies. The new mission is to build a new decision-making system allows to select members who will benefit from the summer subsidies offered by the foundation. This system should be transparent and respects well the benefiting rules and the selection criteria. The following Table 1 shows advantages and the points differences between the ancient system that consists to benefit from the booking stays at the summer resorts affiliated to the foundation, and the new decision support system that consist to benefit from the summer subsidies.

Table 1: Comparison between the ancient system and the new decision support system.

Normal system	**The new decision support system**
The booking process adopts a weekly approach	The benefiting process adopts a seasonal approach
The camping service is based on foundation centers	The camping service is based on summer subsidies
Summer camping locations are determined by the foundation's management	Summer camping locations are chosen by the beneficiaries
Periods of benefiting from the camping service is fixed by the foundation directorate	Periods of benefiting from the camping service is chosen by each beneficiary
The camping service is related to the center's states (Valid or not valid for camping)	The camping service is always valid

A simple comparison of the differences between the old system and the new system demonstrates the privileges and new contributions highlighted to increase the quality of the camping services offered. Indeed, the old booking system was based on a weekly approach, while the new system adopts a seasonal approach, thus offering a more complete overview and a more synthetic management of the beneficiaries' selection process. In addition, the new system allows members to freely choose the date and place of camping, offering greater flexibility and increased customization of the service.

3. Research methodology

3.1. Description of the foundation resources

The foundation includes 35000 members divided into 4 categories. The number of the foundation members in each category is different from each other, this property allows defining part of hotel reservations devoted to members of each category. Given that the budget allocated by the foundation to this camping service is very limited. The foundation provides its members with a number "n<<35000" of summer subsidies, therefore, just a fixed number "n" of members can benefit from these subsidies. These members must have some criteria that qualify them to be selected as beneficiaries.

3.2. Process and rules of benefiting

The new process provides foundation members with two options to benefit from the camping service: the first one is the old process which is the booking stays at the summer resorts affiliated to the foundation. The second one is the new way that allows members of the foundation benefit from summer subsidies offered by the foundation as mentioned in the Figure 1. In the rest of this paper, we focus on treating the second way of benefiting from the camping service because the first one is already described in (Majdoub and Loqman, 2021).

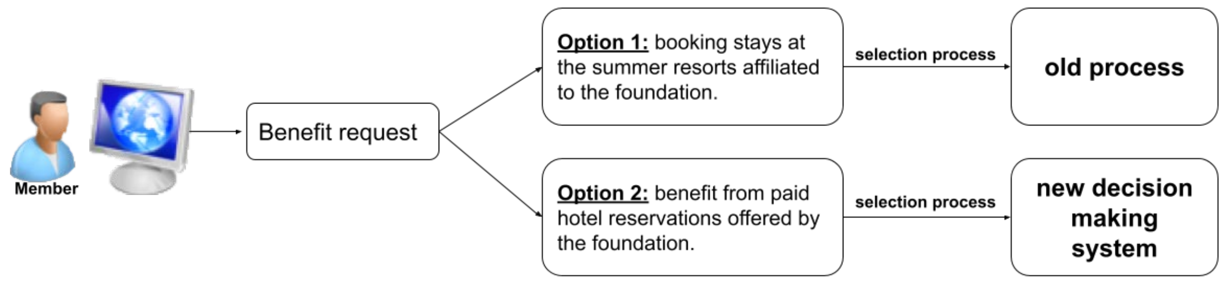


Fig.1: Description of the new camping service management process

The new process is described as the following: In order to benefit from the camping service provided by the foundation, during the summer holiday, members have to fill in a benefit request that contains information needed during the selection process, especially the service type (summer resorts or summer subsidies). On one hand, the selection of members who choose to benefit from booking stays at the foundation's affiliated summer resorts is conducted through the previous system described in \cite{q}. On the other hand, the selection of foundation members who opt to benefit from summer subsidies is made using the newly implemented decision-making system.

The selection process of beneficiaries aims at assign summer subsidies to deserving members. This assignment is subject to some rules that ensure consistency, coherence, and equality between foundation members. These rules are defined as following:

- Choosing the type of service is obligatory. In fact, each member has to decide which type of service to benefit beforehand, because the foundation has a decision system that cannot give the results for members who choose two types of services (summer resorts or summer subsidies).
- Benefiting twice from the camping service during the same camping season is not permitted. Because the budget devoted to the camping service is limited, and the foundation attempts to satisfy the maximum number of members.
- Collisions should not occur. In fact, each summer subsidy can be assigned to one and only one beneficiary.
- The number of selected members must be less than or equal to the number n of available subsidies.
- Categorical proportion must be respected. In other words, the number of selected members from a specific category must not exceed the proportion of subsidies devoted to beneficiaries of this category.

These rules embody the logical relation between the available summer subsidies and beneficiaries, and therefore ensure the reliability of the numerical results obtained.

3.3. Selection criteria of beneficiaries

The major problematic issue for the foundation directorate is that the number of summer subsidies available is very small compared to the number of candidates. Therefore, a number of criteria are taken into consideration to select beneficiaries, these criteria allow making a strict difference between deserving and non-deserving members:

- The date of the last benefit from the camping service of the member.
- The employment date of the member.
- The family situation of the member (the marital status and number of children).
- The age of the member.
- The date of the online benefit request submission in the foundation website.

Using a scoring system, each of these criteria is given a score, and therefore each member of the foundation is provided with a unique weight coefficient.

3.4. Mathematical Formulation of the problem

Our approach utilizes integer programming to optimize resource allocation for summer subsidies. Integer programming offers several advantages, including its ability to handle complex optimization problems with discrete decision variables like selecting beneficiaries or assigning summer subsidies to members. This makes it well-suited to the decisional nature of the summer subsidy allocation problem, where we need to determine how to assign a limited number of summer subsidies to foundation members while considering benefit requests and foundation constraints. Integer programming allows for the creation of precise, tailored solutions that meet specific operational requirements, such as benefit rules and a limited number of summer subsidies. However, Integer programming presents some limitations. One challenge is computational complexity, which can increase significantly with large datasets. In some cases, this might be mitigated by using specialized algorithms or simplifying the model. Despite these limitations, Precision and robustness of integer programming make it a suitable choice for achieving a fair and efficient allocation of summer subsidies.

The new decision-making system is formulated using integer programming, more precisely, it is modeled as constrained assignment problem. In our formulation strategy, summer subsidies and members are represented using algebraic sets, a set of decision variables indicates if a member will benefit from the summer subsidies or not. Sets of constraints ensure that the generated process respects the rules imposed by the foundation directorate, and an objective function allows selecting deserving members based on the selection criteria cited above.

3.4.1. Notation sets

- The foundation member, that has the right to benefit from the camping service. The set of all candidates is denoted by M , e.g. $\mathrm{M} = \{\mathrm{m}_1, \mathrm{m}_2, \ldots, \mathrm{m}_{|M|}\}$.$|M|$: number of all candidates.
- The summer subsidy that will be assigned to a beneficiary. The set of all summer subsidies is denoted by B, e.g. $\mathrm{B} = \{\mathrm{b}_1, \mathrm{b}, \ldots, \mathrm{b}_{|B|}\}$.
- The category to which each member of the foundation belongs. The set of all these categories is denoted C, e.g. $\mathrm{C} = \{\mathrm{c}_1, \mathrm{c}, \ldots, \mathrm{c}_{|C|}\}$.
- The proportion of summer subsidies devoted to every category. The set of all possible proportions is denoted by P, e.g. $\mathrm{P} = \{\mathrm{p}_1, \mathrm{p}_2, \ldots, \mathrm{p}_{|P|}\}$.
- Members of the category $c \in C$ is denoted by M_c.
- The category of foundation members whose proportion of summer subsidies is exhausted. The set of these categories is denoted C_s.
- The proportion of summer subsidies devoted to members of the category $c \in C$ is denoted by P_c.
- The pre-assignment of members to summer subsidies must be also considered in this model. In fact, in some cases, we have to fix some assignments to guarantee good results or to reduce the

problem complexity. The set of these pre-assignments is denoted by PA , e.g. $\mathrm{PA} = \{(\mathrm{m}, \mathrm{b}): \mathrm{m} \in \mathrm{M}, \mathrm{b} \in \mathrm{B}\}$.

3.4.2. Variable sets

The proposed set of variables makes the link between two main notation sets M and B, this binary variable is denoted by x_{mb}, where $m \in M$ and \$ $b \in B$:

$$x_{mb} = \begin{cases} 1, if\ the\ member\ m\ is\ assigned\ to\ the\ summer\ subsidy\ b \\ 0, otherwise \end{cases} \quad (1)$$

3.4.3. Objective function

The benefiting process must assign summer subsidies to deserving foundation members. The candidates should satisfy some criteria that qualify them to benefit from the camping service. These criteria are mainly based on important personal parameters such as age, date of employment, etc. The idea is to integrate these criteria and to combine them to generate a weight coefficient w_m that identifies, in a unique manner, each member $m \in M$. Then, to maximize the objective function defined by the following equation (2):

$$max \sum_{m \in M} \sum_{b \in B} w_m\, x_{mb} \quad (2)$$

Where:

- M : The set of candidates for the camping service.
- B : The set of summer subsidies.
- w_m: The weight coefficient of the member $m \in M$.

This equation intends to assign summer subsidies to foundation members having maximal weight coefficient compared to other members. This weight coefficient is formulated to be unique in order to identify each member.

3.4.4. Weight coefficient calculation

Selection of beneficiaries is based on the selection criteria of each member. Each of these criteria is identified by a score that measures its importance. In order to include these selection criteria in our formulation, we have adopted the same method of the original problem to determine the weight coefficients (Majdoub and Loqman, 2021). This method is summarized as follows (3):

$$\forall\, m \in M, \qquad w_m = w_{m1} + w_{m2} \quad (3)$$

Where:

$$w_{m1} = w_1 + w_2 + w_3 \;\; and\,; \;\; w_{m2} = w_4 + w_5$$

- w_1: Parameter depends on the margin-time between the member's date of employment and the

date of last benefit from the camping service of the same member.
- w_2: Parameter reflects the family situation of the member.
- w_3: Parameter related to the number of children in case of the member is married.
- w_4: Parameter reflects the age of the member.
- w_5: Parameter related to the exact date of making the reservation on the foundation website.

The calculation method adopted to generate values taken by these parameters is carefully formulated to impose a total dominance between these parameters \cite{q}. In fact, the parameter $ w_1 $ dominates all the others parameters ($w_1 > w_2 + w_3 + w_4 + w_5$), the same thing for w_2 that also dominates the other parameters ($w_2 > w_3 + w_4 + w_5$),...
This property ensures that if two or more candidates have the same value for the w_1 parameter, the other parameters will strictly differentiate between weight coefficients of these candidates.
The following example shows this weight coefficient property. Consider the personal information of three members a_1, a_2, and a_3 presented in the Table 2:

Table 2: Personal information of the three members a_1, a_2, and a_3.

Member	Date of the last benefit	Family situation	Number of children	Member age	Date of the online benefit request submission
a_1	**3**	**Single**	**0**	**30**	**21/05/2021 at 16:24:08**
a_2	**2**	**Married**	**3**	**41**	**22/05/2021 at 09:45:32**
a_3	**3**	**Single**	**0**	**29**	**20/05/2021 at 13:04:51**

Given that the online request submission period was between 01/05/2021 at 00:00:00 and 01/06/2021 at 00:00:00, the weight coefficient associated with to each of these members, using the calculation method adopted by (Majdoub and Loqman, 2021) is summarized in the following Table 3:

Table 3: Calculation of the weight coefficients of the three members a_1, a_2, and a_3.

Member	w_1	w_2	w_3	w_{m1}	w_4	w_5	w_{m2}	w_m
a_1	**30**	**2**	**0**	**32**	**0.461538**	**0.275829**	**0.737367**	**32.368683**
a_2	**20**	**3**	**6**	**26**	**0.630769**	**0.253112**	**0.883881**	**29.441940**
a_3	**30**	**2**	**0**	**32**	**0.446153**	**0.315165**	**0.761318**	**32.380659**

From this example, we notice that in the a_1 and a_2 case, the principal weight w_{m1} presents a strict dominance. In the case where two members have the same principal weight coefficient, the second one w_{m2} allows to make a strict difference between the members as it is shown in the a_1 and a_3 case.

3.4.5. Constraints sets

The benefit from the camping service is subject to a number of rules imposed by the foundation directorate. These rules will be modeled as sets of constraints that project the rules in the mathematical formulation.

Uniqueness constraints:

- This equation (4) reflects the first rule cited in the previous section, it ensures that each candidate has the right to benefit at most once and only once from the camping service during the summer holiday:

$$\forall\, m \in M: \sum_{b \in B} x_{mb} \leq 1 \qquad (4)$$

- Each summer subsidy shall be assigned to one candidate, more precisely:

$$\forall\, b \in \mathrm{B}: \quad \sum_{m \in \mathrm{M}} x_{mb} \;\leq\; 1 \qquad (5)$$

Capacity constraints:

The total number of beneficiaries must be less than or equal to the number of summer subsidies fixed by the foundation directorate. This rule is modeled by the following equation:

$$\sum_{m \in M} \sum_{b \in B} x_{mb} \;\leq\; |B| \qquad (6)$$

Where $|B|$ presents the number of summer subsidies available.

Consecutiveness of members constraints:

To give priority to candidates having high weight coefficients and to eliminate automatically the others, the following constraints set ensures this property.

$$\forall\, c \in C, \forall\, m_1, m_2 \in M_c \left(w_{m1} > w_{m_2}\right): \sum_{b \in B} x_{m2b} \;\leq\; \sum_{b \in B} x_{m1b} \qquad (7)$$

Where w_m denotes the weight coefficient of the candidate m.

Proportion constraints:

For every category, the number of beneficiaries must respect the proportion of summer subsidies devoted to members of this category, more precisely:

$$\forall\, c \in C: \quad \sum_{m \in M_c} \sum_{b \in B} x_{mb} \;\leq\; P_c \qquad (8')$$

Where P_c is the proportion of summer subsidies devoted to the category $c \in C$.

In case that the number of benefit requests of a specific category is less than their proportion of summer subsidies. The remaining number of summer subsidies will be redistributed to other members belonging to other categories whose proportion of summer subsidies is exhausted. The aim is to satisfy the maximum number of members. This property is formulated using the following equation (8) that replaces the previous equation (8′).

$$\forall\, c \in C: \quad \sum_{m \in M_c} \sum_{b \in B} x_{mb} \;\leq\; P_c + q_c \qquad (8)$$

Where q_c presents the proportion of subsidies of the category c after redistribution of the remaining subsidies to members categories who's their proportion of subsidies has been exhausted. This proportion is calculated using heuristic described by the following Algorithm:

Input: Number of benefit requests $|M_c|$ and the proportion P_c for each $c \in C \setminus C_s$
Output: Part of summer subsidies q_c of each category $c \in C \setminus C_s$.

for $c \in C \setminus C_s$ **do**
  Calculate, $n_c = P_c - |M_c|$
end for
$N \leftarrow \sum_{c \in C \setminus C_s} n_c$
if $c \in C_s$ **then**
  $u_c \leftarrow 0$
else
  $u_c \leftarrow \lfloor N * \frac{P_c}{\sum_{c' \in C_s} P_{c'}} \rfloor$
end if
$r \leftarrow n - \sum_{c \in C \setminus C_s} p_c$
if $c \in \{c_i \in C \setminus C_s, i = 1, ..., r\}$ **then**
  $q_c \leftarrow u_c + 1$
else
  $q_c \leftarrow u_c$
end if

Algorithm1: Algorithm to calculate the proportion of remaining summer subsidies of categories c $\in C \setminus C_s$.

Pre-assignment constraints:

This set of constraints gives the possibility to fix some assignment before starting the process. This property allows, in special cases, to assign one or more candidates to a determined hotel reservation, or to fix some assignments that increase the complexity of the problem. This property helps the system to generate good results in a short amount of time. This property is formulated by the following equation:

$$\forall (m, b) \in PA: \quad x_{mb} = 1 \qquad (9)$$

4. Results and discussion

In order to prove efficiency of the proposed solution, we implement it and we instantiate it using real-data of the Mohammedia foundation of justice. The data include benefit requests of the foundation members during the camping season of the years 2021, 2022, and 2023. Then, we evaluate the obtained results by calculating suitable performance parameters such as the assignment rate, filling rate, execution time... Thus, we test performance of the system by analyzing evolution of execution time and iterations number needed to achieve optimal solution.

The foundation makes available a fixed number of summer subsidies to keep the camping service available to the foundation members. The beneficiaries should satisfy the selection criteria imposed by the foundation directorate. Using a scoring system, these criteria are projected in the mathematical formulation to build the weight coefficient that identifies each member as it is shown in the weight coefficients calculation section.

4.1. Experience conditions and hypothesis

We performed the test on the foundation data during the hot season of the year 2021, 2022, and 2023 during which the number of foundation members was 35000. The proportions of the four categories are the same as the old ones cited by (Majdoub *et al.*, 2021), and the number of summer subsidies available to execute the booking operation is fixed by calculating proportion of summer subsidies devoted to each category.

The proportion of each category is determined based on the existing ratio between the total number of foundation members and the number of members of this category. The Table 4 summarizes the data used in this experimental case.

Table 4: Proportions of summer subsidies of each category.

Category	Category proportion (%)
C_1: Magistrates	**17%**
C_2: Officials of the foundation	**2%**
C_3: Officials of the Justice Ministry	**47%**
C_4: Officials of the Prison administration and reintegration	**34%**

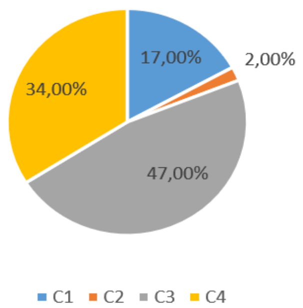


Fig.2: Proportions of summer subsidies of each category

4.2. Calculation environment

The experimental part is compiled in a standard environment characterized by \$ 2.80GHz \$ Intel(evo), Core(TM) i7-1165G7 processor, with 16GB of RAM running under windows 11. The software package IBM ILOG CPLEX optimization studio v12.2 offered by IBM has been used to perform all the calculation.

4.3. Results presentation

In this part, we present the results obtained by testing the proposed model on the foundation data of the camping season of the years 2021, 2022 and 2023. These results are presented in Table 5 and Figures 2, 3, and 4 that summarize the benefit requests, devoted proportions, and the number of members benefiting from summer subsidies of each category.

The process is evaluated by the assignment rate τ_c that is calculated for each foundation category, and a filling rate ρ using the following equations:

$$\forall\, c \in C, \qquad \tau_c = \frac{N_c}{\min(n_c, P_c)} \quad , \quad \rho = \frac{T_{ass}}{T_{av}} \qquad (10)$$

Where, n_c is the number of benefit requests of members belonging to the category c , P_c is the proportion of summer subsidies devoted to the category c, N_c presents the total number of beneficiaries from this category c, T_{ass} is the total number of beneficiaries that represents the number of assigned members to the camping service, and T_{av} is the number of all summer subsidies available.

Table 5: Assignment results obtained by the test of our solution on data of the camping seasons of the years 2021, 2022 and 2023.

Year	Category	n_c	N_c	P_c	τ_c	ρ	E-time (sec)	N_{iter}	Objective
2021	C_1	160	160	255	100%	100%	175.91	4158	1.71113e+05
	C_2	59	59	30	100%				
	C_3	1396	794	705	100%				
	C_4	487	487	510	100%				
	Total	2102	1500	1500	100%				
2022	C_1	111	85	85	100%	100%	251.17	3612	1.24899e+05
	C_2	39	10	10	100%				
	C_3	1051	235	235	100%				
	C_4	264	170	170	100%				
	Total	1465	500	500	100%				
2023	C_1	102	85	85	100%	100%	8.17	1507	7.72096e+04
	C_2	23	10	10	100%				
	C_3	564	235	235	100%				
	C_4	176	170	170	100%				
	Total	865	500	500	100%				

The diagrams below illustrate the assignment results from testing our solution with data from the camping seasons of 2021, 2022, and 2023. These diagrams show, for each category c, the number of benefit requests from members n_c, the proportion of summer subsidies devoted P_c, and the total number of beneficiaries N_c.

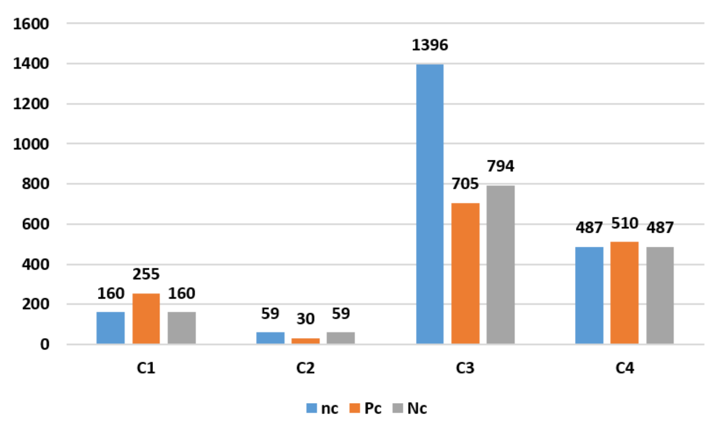


Fig.3: Assignment results of the camping seasons of the years 2021 using our solution.

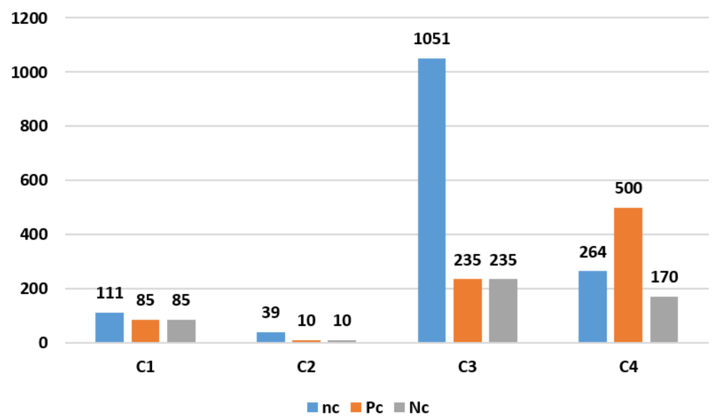


Fig.4: Assignment results of the camping seasons of the years 2022 using our solution.

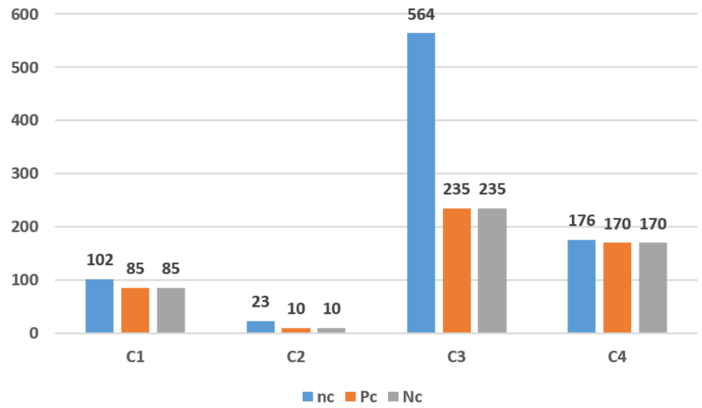


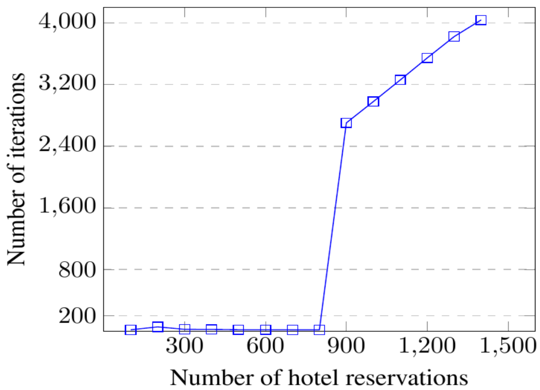
Fig.5: Assignment results of the camping seasons of the years 2023 using our solution.

The Table 5 provides a detailed description of the three latest camping seasons conducted by the foundation. Each session includes specific data, such as the demand number for each category and the proportion of summer subsidies devoted to each category. Additionally, the results obtained using our proposed decision-making solution for each session are presented, including the number of beneficiaries in each category, assignment rates, filling rates, execution time, iterations number required to achieve the optimal solution, and the corresponding value of the objective function.
This Table 5 and the Figures 2, 3, and 4 elucidate the assignment rate and the filling rate over the three camping seasons is 100%. The 100% assignment rate across all categories demonstrates the model's effectiveness in maximizing subsidy utilization while respecting category-specific quotas. This is particularly noteworthy given the varying demand levels across categories. It is also worth noting that during the 2021 camping season, the assignment rate for category C_3 exceeded 100%, which can be interpreted by the effect of constraints (8), which adjust the category proportions in the case of unassigned summer subsidies. We can also remark that the filling rate is 100\% in each of the three seasons. That confirm the perfect management of summer subsidies.

To be sur that our solution respects all rules of benefiting, we conducted a detailed analysis of the number of beneficiaries of each category, the evolution of execution time and the number of iterations required to achieve an optimal solution, by fixing the demand number of the camping season of 2021 in 2102 demands and changing the number of summer subsidies. By monitoring the changes in execution time and iterations count, we were able to evaluate the efficiency and effectiveness of our solution as it scaled with increasing numbers of summer subsidies. The following Table 6 shows details of this analysis.

Table 6: Evolution of the number beneficiaries, iterations and execution time required to achieve the optimal solution

Number of summer subsidies	Category				N_{iter}	E-time (sec)
	C_1	C_2	C_3	C_4		
100	17	2	47	34	17	2.91
200	34	4	94	68	55	5.91
300	51	6	141	102	23	9.75
400	68	8	188	136	22	13
500	85	10	235	170	18	17.51
600	102	12	282	204	18	22.53
700	119	14	329	238	17	28.53
800	136	16	376	272	16	38.97
900	153	18	423	306	2703	46.23
1000	160	24	473	343	2979	52.39
1100	160	30	526	384	3260	89.60
1200	160	36	581	423	3546	107.13
1300	160	43	634	463	3823	127.67
1400	160	56	697	487	4039	136.77



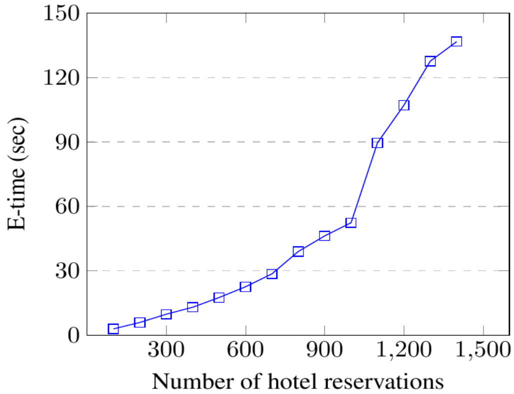


Figure 5: Evolution of the number of iterations, execution time required to achieve the optimal solution

From the Table 6 and the Figure 5, we can remark that, for each instance, results of the system are compatible with the benefiting rules regarding proportions, capacities, and consecutiveness constraints. Moreover, evolution of the execution time and the iterations number needed to achieve these results are advantageous and normal due to the combinatorial nature of the problem that leads to an increase in the number of variables and equations in the mathematical formulation of the problem of selecting beneficiaries, which consequently leads to an increase in the number of arithmetic operations required to find the optimal solution of the problem. These results justify the effectiveness of our decision support system and its capability to select beneficiaries of summer subsidies.

4.4. Results discussion

From the Table 5 and the Figures 2, 3, and 4, we remark that the assignment ratio is 100% for all existing categories, it's clear that our model implemented in the decision support system of the camping service works perfectly using the foundation data experimented, and it presents a best alternative solution to perform the camping service. We remark also that, for example, for the category C_3 of the 2021 session, the proportion devoted to this category is smallest than the beneficiaries assigned, that is interpreted by the heuristic effect given by constraints (8), that redistribute the reminding hotel reservations upon the categories whose proportion of is exhausted. At this level, we can touch the importance of the proposed heuristic in managing resources and maximizing the beneficiary's number, evolution of the execution time and iterations number needed to achieve optimal solution is generally normal because of the combinatorial aspect of the problem.

Our model's ability to achieve 100% assignment and filling rates outperforms similar resource allocation systems reported in the literature (Liu and Fan, 2018). This experience confirms the practicality of our proposed solution in managing the camping service using summer subsidies. It provides members with unrestricted freedom to choose their preferred location and camping date, offering a versatile and alternative solution. In contrast to the restrictive approach highlighted in (Majdoub *et al.*, 2021), which confines members to select residences solely from foundation centers.

This solution has addressed the new requirements of the previous system, allowing foundation members to benefit from both foundation centers and summer subsidies, thereby increasing the number of beneficiaries of the camping service. However, a limitation of this approach is its computational complexity for high-size instances. As the number of beneficiaries and the number of summer subsidies increase, the computational resources and time required to find optimal solutions can become significant due to the increased number of arithmetic operations needed to achieve optimal solutions. This complexity has the potential to impact the efficiency of the allocation process. The generated results have been adopted by the foundation directorate for its beneficiary selection operations in the 2021, 2022, and 2023 sessions.

This solution has accomplished the new faced requirements of the ancient system, and it to give foundation member the right of benefiting from both foundation centers and summer subsidies in order to increase the beneficiaries number from the camping service. The generated results have been adopted by the foundation directorate in its beneficiary's selection operation of the 2021, 2022, and 2023 session.

5. Conclusion

This study presents a novel approach to managing summer subsidy allocation using integer programming. The developed model successfully addresses the complex challenge of optimizing resource allocation while respecting multiple constraints and member preferences. Applied to real data from a Moroccan foundation, our approach achieved 100% assignment and filling rates across three camping seasons, demonstrating its effectiveness in maximizing benefit utilization.

The model's ability to handle seasonal allocation, rather than weekly, and its flexibility in allowing members to choose their preferred camping locations and dates represent significant improvements over previous systems. These features not only enhance member satisfaction but also increase operational efficiency.

This study contributes to the literature on resource allocation by demonstrating the effectiveness of a tailored integer programming approach in the specific context of summer subsidy allocation. The successful application of this model to real-world data extends our understanding of how operational research techniques can be applied to complex social benefit systems.

Future research could explore the model's applicability to different types of social benefits or investigate the integration of machine learning techniques to further optimize the allocation process based on historical data and member preferences.

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