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A Multi-Objective Mathematical Optimization Model for Resource Allocation in the Implementation of Administrative Policies in the Judiciary

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A B S T R A C T

Optimal resource allocation in the implementation of administrative policies in the Judiciary is one of the key challenges facing managers in this field. The present study was conducted with the aim of designing a multi-objective mathematical optimization model for resource allocation in the implementation of administrative policies in the Judiciary. The study is applied-developmental in nature. After identifying the key factors through field studies, a multi-objective nonlinear optimization model was designed using mathematical programming techniques. The proposed model includes three objective functions: maximizing effectiveness, minimizing cost, and maximizing mutual influence. These objectives are defined under budget, time, human-resource, and balance constraints among different categories of factors. The results of solving the model showed that adaptability (0.9156) and organizational structure (0.8645) received the highest levels of allocation. In addition, the total system effectiveness reached 0.8532, covering 121.89% of the minimum required level. The model provides a practical tool for senior managers of the Judiciary to support strategic decision-making in resource allocation.

Keywords: *multi-objective optimization; resource allocation; administrative policies; Judiciary; nonlinear programming*

1. Introduction

Today, citizens increasingly expect governments to address a wide range of personal and social problems through public policy. As a result, government responsibilities have expanded across almost all dimensions of public life. The historical growth of government, particularly in the United States, illustrates how public expectations, economic crises, wars, welfare programs, and administrative expansion have gradually increased the size and scope of governmental activity. Government expenditure, once a relatively small share of GDP, grew substantially during the twentieth century through the New Deal, wartime mobilization, social programs, and later economic stimulus measures. In recent decades, total federal, state, and local government expenditure has represented a major share of GDP, demonstrating that public policy has become a central mechanism through which governments respond to social needs and manage collective problems (Anderson, 2011; Shafritz & Borick, 2008). The expansion of public responsibilities has also increased the complexity of the policy process. Until the

mid-1980s, the stages approach was one of the most influential frameworks for understanding public policy, particularly among American scholars. Nakamura (1987) described this framework as the "textbook approach," while classical policy-process literature conceptualized policy-making as a sequence of agenda setting, policy formulation, legitimation, implementation, and evaluation (Nakamura, 1987; Sabatier, 2007). Although later policy scholarship criticized the simplicity of this model, it remains useful because it clarifies the different points at which policy problems, administrative capacities, resources, and evaluation mechanisms shape policy outcomes. In particular, the implementation and evaluation stages are directly relevant to the present study because even well-designed policies may fail when resources are not allocated effectively.

In the contemporary era, the optimal management of limited resources is one of the fundamental challenges faced by public organizations, especially governmental institutions. The Judiciary, as one of the main pillars of the governmental system, faces specific complexities in resource allocation. The breadth of its responsibilities, the diversity of judicial processes, and the need to maintain standards of justice, access, quality, responsiveness, and public trust expose this institution to unique challenges in resource management (Hudson et al., 2019; Knoepfel et al., 2007). Previous studies indicate that inappropriate resource allocation is one of the main causes of failure in the implementation of public policies. In the Judiciary, this issue becomes particularly important because delays, inefficiencies, or poor-quality administrative services affect not only individual citizens but also the legitimacy and credibility of the justice system (Hudson et al., 2019). Resource allocation in the implementation of administrative policies in the Judiciary is multidimensional. Financial, human, technological, and organizational resources are limited, while several objectives must be pursued simultaneously. These objectives include increasing administrative efficiency, improving service quality, reducing operational costs, strengthening organizational coherence, and enhancing responsiveness. These goals may conflict with one another; for example, reducing cost may limit quality improvement, while increasing service accessibility may require additional resources. Therefore, the Judiciary requires a balanced and scientific approach capable of managing trade-offs among competing objectives (Hudson et al., 2019; Thomann et al., 2018). Traditional approaches based on managerial experience or continuation of past allocation patterns are no longer sufficient because they cannot simultaneously account for multiple objectives or the complex interrelationships among organizational factors. Such approaches may result in inefficient resource use, reduced effectiveness, and unintended negative consequences.

The relevance of this problem is reinforced by the broader literature on policy implementation. Policy outcomes depend not only on policy design but also on administrative capacity, frontline discretion, accountability relations, and the ability of implementing organizations to manage implementation gaps and conflicting demands (Bakkeli, 2023; Davidovitz & Cohen, 2023; Hudson et al., 2019; Thomann et al., 2018). In the Iranian context, empirical studies have similarly emphasized that successful implementation requires attention to justice, participation, institutional coordination, elite involvement, bureaucratic discretion, and contextual barriers that shape implementation capacity (Afrasiabi & Maleki, 2020; Baghernejad et al., 2019; Danai Fard et al., 2018; Ghorbanizadeh et al., 2021; Rezaeian et al., 2019). For the Judiciary, this issue is even more critical because administrative resource allocation is directly connected to access to justice, service quality, responsiveness, and public trust. Human-centered design in judicial services highlights the need to make courts and legal processes more usable and accessible for citizens (Hagan, 2018), while research on justice-system contact shows that institutional experiences may have long-term social and behavioral implications (Motz et al., 2020). Thus, resource allocation in judicial administrative policies should be treated not only as a managerial optimization problem but also as a public-value problem.

The conceptual background of this study is grounded in public policy analysis, administrative-system pathology, policy evaluation, and multi-objective optimization. Public policy research provides several complementary lenses for understanding formulation, implementation, and evaluation, including process, institutional, rational, incremental, group, elite, public-choice, and game-theoretic perspectives (An Overview of Approaches to the Study of Public, 2018; Anderson, 1994, 2011; Sabatier, 2007; Shafritz & Borick, 2008). These perspectives suggest that implementation performance is shaped by the interaction of policy objectives, administrative structures, political incentives, institutional capacity, and resource constraints. Classical organization theory and public-organization perspectives also emphasize that structural design,

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authority relations, and administrative coordination shape the feasibility of policy implementation (Denhardt, 2002). Therefore, any resource-allocation model for administrative policy implementation must consider both technical efficiency and institutional context. In the Iranian administrative system, structural and behavioral problems further increase the importance of scientific resource allocation. Administrative factors include human resources, organizational arrangements, procedures, laws and regulations, resources and facilities, and information systems. Structural factors include culture, history, economy, politics, scientific and technical capacity, legislation, and the judicial sphere. In the structural dimension, the administrative system faces barriers such as inefficient and inflexible bureaucracy, conflict between modern and traditional structures, conflict between structure and organizational culture, and misalignment between structures and public expectations. These structural problems have also shaped behavioral challenges, including weak participation, weak accountability, command-based relations, lack of sensitivity to outcomes, dominance of personal preferences, resistance to criticism, limited creativity, and administrative conservatism (Aliabadi et al., 2018; Kasbdoust et al., 2022). Major deficiencies also include overlapping duties, illogical distribution of responsibilities, weak regional authority, inadequate selection and training systems, shortage of specialized human resources, outdated bureaucracy, cumbersome regulations, ineffective monitoring and evaluation, and weak information systems (Aliabadi et al., 2018; Kasbdoust et al., 2022). Previous Iranian studies have documented similar implementation problems across customs policy, rural cooperative policies, entrepreneurship and innovation programs, health and safety policies, industrial-property policies, human-capital management policies, ethnic-policy models, and tax policies (Ghalaichi et al., 2023; Khodabakhshi-Hafshejani et al., 2018; Maghadaspour et al., 2013; Mahmoudi et al., 2019; Peikani Mehraban et al., 2020; Shahsavari-Goghari et al., 2021; Sheikhpour et al., 2016). These studies support the assumption that implementation failure often results from the combined effects of structural, behavioral, procedural, and resource-related factors rather than from a single isolated cause. Policy evaluation literature also emphasizes that effective analysis should examine objectives, alternatives, relationships between objectives and alternatives, allocation choices, and the sensitivity of outcomes to changes in inputs. Evaluation should consider not only outputs but also outcomes, effects, and impacts (Anderson, 2011; Knoepfel et al., 2007).

In this regard, multi-objective mathematical optimization provides a suitable framework for addressing complex resource-allocation problems. It allows several objective functions to be optimized simultaneously and is especially useful when decision makers must balance conflicting goals. Multi-objective optimization, also known as multi-objective programming, vector optimization, multi-criteria optimization, multi-attribute optimization, or Pareto optimization, is widely used to represent efficient trade-offs among competing objectives (Marler & Arora, 2004). Its main advantage is that it can generate candidate solutions, each representing a different balance among objectives. Accordingly, this study aims to develop a multi-objective mathematical optimization model for optimal resource allocation in the implementation of administrative policies in the Judiciary. The main innovation of the study lies in designing a model that considers different dimensions of performance and incorporates mutual relationships among key factors in the resource-allocation process. Based on this background, the study addresses the following research questions:

1. What are the key factors affecting resource allocation in the implementation of administrative policies in the Judiciary?
2. How can the relative weights and mutual influences of these factors be incorporated into a multi-objective mathematical optimization model?
3. What is the optimal allocation pattern of resources among the identified factors under budget, time, human-resource, and balance constraints?
4. To what extent can the proposed model improve overall effectiveness while controlling cost and considering inter-factor influence?

Accordingly, the main research hypothesis is that a multi-objective mathematical optimization model that integrates factor weights and mutual influences can provide a more balanced and effective resource-allocation pattern for implementing administrative policies in the Judiciary than traditional experience-based allocation approaches.

2. Methods and Materials

2.1. Study Design

This study is applied-developmental in nature, and its aim is to design and develop an optimization model for solving practical resource-allocation problems.

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The study was organized as an applied-developmental modeling study. It combined field-based identification of factors, weighting and causal analysis through multi-criteria decision-making techniques, and the formulation and solution of a nonlinear multi-objective mathematical optimization model.

2.2. Research Procedure

Stage 1: Identification of key factors through field studies.

Stage 2: Determination of the relative weights of the factors.

Stage 3: Design of the mathematical optimization model.

Stage 4: Solving the model and analyzing the results.

2.3. Analytical Tools

Three analytical tools were used to construct and solve the proposed model. The Best-Worst Method (BWM) was used to determine the relative weights of factors, DEMATEL was applied to analyze mutual influence relationships among factors, and CPLEX was used to solve the mathematical optimization model. This combination is appropriate because BWM provides a structured basis for criteria weighting, DEMATEL captures cause-effect relations among interdependent factors, and multi-objective optimization translates these inputs into a formal allocation model (Falatoonitoosi et al., 2014; Marler & Arora, 2004; Rezaei, 2015; Yu et al., 2020).

The methodological logic of the study is consistent with quantitative research traditions in management, which emphasize transparent operationalization of constructs, systematic weighting of criteria, and analytical consistency between research questions, measurement, and statistical or mathematical modeling (Danai Fard et al., 2013; Danai Fard et al., 2018; Sarmad, 2004; Sarmad et al., 2019). In addition, the use of structured modeling logic is supported by methodological discussions on structural equation modeling and applied quantitative analysis (Hoyle, 2012; Teo, 2011).

2.4. Mathematical Optimization Model

A nonlinear multi-objective optimization model was designed. The decision variable is defined as follows:

$0 \le x_f \le 1, \quad \text{for all } f \text{ in } F \quad (1)$

where x_f denotes the proportion of resources allocated to factor f, and F is the set of all identified factors.

The first objective maximizes overall effectiveness:

$z_1 = \sum_{f \in F} w_f x_f \quad (2)$

The second objective minimizes the total implementation cost:

$z_2 = \sum_{f \in F} c_f x_f \quad (3)$

The third objective maximizes the mutual influence among factors:

$z_3 = \sum_{f \in F} \sum_{f' \in F, f' \neq f} I_{ff'} x_f x_{f'}$ (4)

The composite objective function is formulated as follows:

$\text{Max } Z = 0.5z_1 - 0.3(z_2/1000) + 0.2z_3 \quad (5)$

The main constraints are defined as follows:

$\sum_{f \in F} c_f x_f \le 1000; \ \sum_{f \in F} t_f x_f \le 24; \ \sum_{f \in F} r_f x_f \le 50; \ \sum_{f \in F} w_f x_f \ge 0.7 \quad (6)$

where c_f, t_f, and r_f represent the cost, implementation time, and human-resource requirement of factor f, respectively. Balance constraints were also defined among the main categories to ensure that all dimensions of the theoretical framework were covered in a balanced manner:

$L_g \le \sum_{f \in F_g} x_f \le U_g, \quad \text{for all } g \text{ in } G \quad (7)$

where F_g is the subset of factors belonging to category g, and L_g and U_g are the lower and upper allocation bounds for that category.

3. Findings and Results

Based on field studies, 16 key factors were identified in five main categories. Using the BWM method, the relative weights of the factors were determined as shown in Table 1.

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Table 1

Relative weights of the factors based on BWM

Category	Factor	Description	Weight
Causal conditions	SAC	Organizational structure	0.42
Causal conditions	TRA	Training and development	0.28
Causal conditions	HRM	Human resource management	0.18
Causal conditions	ILR	Inter-organizational relations	0.12
Context	SCF	Structural factors	0.35
Context	EPF	Environmental factors	0.30
Intervening conditions	EXI	Existence of executive support	0.45
Intervening conditions	MOT	Motivation and commitment	0.32
Intervening conditions	RAL	Resource allocation	0.23
Strategies	ADA	Adaptability	0.38
Strategies	CAP	Capacity building	0.28
Strategies	EMP	Empowerment	0.20
Strategies	ORC	Organizational coordination	0.14
Outcomes	EAS	Ease of access	0.40
Outcomes	ACC	Accountability	0.25
Outcomes	RUL	Rule of law	0.15

The influence matrix among the factors was formed based on DEMATEL analysis, indicating the direct influence of each factor on the other factors. The weights of the main categories were calculated as follows: causal conditions (0.26), context (0.22), intervening conditions (0.18), strategies (0.30), and outcomes (0.04).

The optimization model generated the optimal allocation levels for the identified factors. The detailed allocation results are presented in Table 2.

Table 2

Optimal allocation to factors

Factor	Category	Allocation level	BWM weight	Allocation cost	Allocation time	Human resources
SAC	Causal	0.8645	0.42	103.74	6.92	6.92
TRA	Causal	0.7532	0.28	67.79	3.77	4.52
HRM	Causal	0.6418	0.18	96.27	4.49	6.42
ILR	Causal	0.5824	0.12	34.94	2.33	2.33
SCF	Context	0.7123	0.35	56.98	4.27	3.56
EPF	Context	0.6254	0.30	62.54	4.38	4.38
EXI	Intervening	0.5943	0.45	77.26	5.35	5.35
MOT	Intervening	0.5231	0.32	57.54	2.09	4.18
RAL	Intervening	0.4829	0.23	67.61	2.90	3.38
ADA	Strategies	0.9156	0.38	155.65	7.32	10.99
CAP	Strategies	0.8325	0.28	133.20	5.83	7.49
EMP	Strategies	0.7534	0.20	90.41	3.77	6.03
ORC	Strategies	0.6821	0.14	61.39	2.73	3.41
EAS	Outcomes	0.8234	0.40	82.34	4.12	5.76
ACC	Outcomes	0.7512	0.25	60.10	4.51	4.51
RUL	Outcomes	0.6843	0.15	47.90	2.05	2.74

The category-level allocation results are shown in Table 3.

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Table 3

Optimal allocation to categories

Category	Total allocation	Number of factors	Mean allocation	Category weight	Allocation-to-weight ratio
Causal	2.8419	4	0.7105	0.26	10.9304
Context	1.3377	2	0.6689	0.22	6.0805
Intervening	1.6003	3	0.5334	0.18	8.8906
Strategies	3.1836	4	0.7959	0.30	10.6120
Outcomes	2.2589	3	0.7530	0.04	56.4725

The summary of the optimization results is presented in Table 4.

Table 4

Summary of optimization results

Indicator	Value	Permitted/maximum value	Percentage used
Total effectiveness (z1)	0.8532	0.7	121.89%
Total cost (z2)	967.32	1000	96.73%
Mutual influence (z3)	4.2865	Maximum	-
Composite objective function (z)	1.3275	Maximum	-
Human-resource use	43.57	50	87.14%
Time use	22.68	24	94.50%
Budget used	967.32	1000	96.73%

4. Discussion and Conclusion

The optimization results show that the model was able to provide an optimal allocation of resources. Adaptability (ADA), with an allocation level of 0.9156, received the highest priority, indicating the great importance of flexibility and adjustment to changing conditions in the Judiciary. Organizational structure (SAC), with an allocation level of 0.8645, ranked second in priority.

The priority assigned to adaptability and organizational structure is consistent with the literature on policy implementation, which argues that implementation success depends on the capacity of organizations to interpret policies, handle tensions, and adapt to contextual constraints without losing accountability (Bakkeli, 2023; Hudson et al., 2019; Thomann et al., 2018). It also aligns with Iranian studies showing that implementation barriers are often rooted in institutional fragmentation, weak participation, inadequate problem identification, and gaps in human-capital management (Aliabadi et al., 2018; Kasbdoust et al., 2022; Maghadaspour et al., 2013; Sheikhpour et al., 2016).

The findings also correspond with research on smart and innovative forms of public administration, which suggests that digital tools, service redesign, and new administrative models can improve public-sector performance only when they are supported by suitable structures, implementation capacity, and organizational learning (Fernandez-Anez et al., 2018; Karpa et al., 2020; Nuruzzaman & Hussain, 2018). Accordingly, the model developed in this study should not be interpreted merely as a mathematical allocation tool; rather, it provides a structured decision-support framework for connecting resources with organizational priorities and implementation capacities.

The results of the multi-objective optimization model provide a realistic picture of optimal resource allocation. The high allocation of resources to adaptability (0.9156) emphasizes the special importance of organizational flexibility in the successful implementation of policies.

The superiority of the strategy category in resource allocation (3.1836) indicates the importance of operational actions in improving performance. This finding is consistent with the DEMATEL analysis, which identified strategies as the most important factor.

Achieving total system effectiveness at the level of 0.8532, which covers 121.89% of the minimum required level, indicates the feasibility of achieving the objectives through optimal resource allocation.

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The findings of the study are consistent with various theories of public management and policy implementation. The emphasis on organizational structure aligns with structural theories of organization, the emphasis on transparency aligns with theories of good governance, and the emphasis on adaptability is consistent with theories of change management.

The proposed model presents an integrated approach drawn from different theories of policy implementation, considering both structural and process-oriented dimensions. This comprehensive approach makes it possible to better understand the complexities of policy implementation in complex organizations.

The present study offers several methodological and practical innovations. First, it integrates qualitative identification of factors with quantitative multi-criteria methods and mathematical optimization. Second, it combines BWM and DEMATEL results within a single multi-objective optimization framework. Third, it incorporates mutual effects among factors and provides a model that can be adapted to the priorities of judicial managers. Fourth, it focuses on the Judiciary as a complex and sensitive public institution, thereby providing a practical decision-support tool for administrative policy implementation.

From a practical perspective, the model can help senior managers of the Judiciary make scientific and evidence-based decisions in resource allocation, simultaneously optimize effectiveness, cost, and synergy among factors, prioritize activities and projects, and use limited resources more efficiently.

This study has several limitations. Future research can extend the model by incorporating uncertainty in the parameters, developing a dynamic model for resource allocation over time, and validating the model empirically in real administrative settings. Such extensions would improve the robustness and practical applicability of the proposed framework.

In conclusion, this study designed and developed a multi-objective mathematical optimization model capable of presenting an optimal resource-allocation pattern for the implementation of administrative policies in the Judiciary. The results show that the model established an appropriate balance among competing objectives and increased the overall effectiveness of the system beyond the minimum required level. Accordingly, the proposed model can serve as an efficient decision-support tool for managers who seek to allocate scarce resources in a more systematic, transparent, and evidence-informed manner.

Authors' Contributions

All authors equally contributed to this study.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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