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A bi-objective model for civil court scheduling problem with pragmatic procedures and factors under uncertainty

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Abstract *– This study introduces a novel framework for planning and scheduling the handling of litigation cases in a judicial system. For this purpose, an unprecedented, bi-objective optimization model is proposed for scheduling family and civil cases in different courts, including primary, review, and supreme. In this regard, a broad range of pragmatic procedures and factors are considered, including different courts, the structuring of the process of judicial cases, the diversity of lawsuits and their miscellaneous cases, specialized chambers in courts, judges with different specializations, the frequency of reviewing cases in courts, filing objections, priority of cases, and permissible waiting time for handling cases and issuing their verdicts. More importantly, a sharing mechanism is embedded in the scheduling procedure to balance the workload across the chambers of the primary court, given the high volume and variety of cases. Furthermore, since the uncertainty in case handling times is an undeniable concern in planning such problems, the set-induced robust optimization approach is applied to address it. Finally, a real case study of Iran's judicial system is examined to illustrate the applicability and validation of the proposed model. The results showed that the considered sharing mechanism can reduce excess service capacity by 28%.*

Keywords– *Court scheduling; Civil cases; Sharing; Judicial system; Uncertainty.*

I. INTRODUCTION

Countries around the world differ widely in the quality of their judicial systems. In some of these systems, courts resolve disputes and lawsuits quickly, fairly, and economically. While in others, they are time-consuming, inefficient, biased, incompetent, or even corrupt. These differences are significant not only for the litigants but also for societies and governments (Jain et al., 2023; Gupta & Bolia, 2024). This problem is especially evident in developing and transition economies, although there are significant differences in court quality across developed countries as well (Grajzl & Silwal, 2020; Castelliano et al., 2021; Pereira et al., 2022).

In recent years, the courts in almost all countries have faced the problem of an increasing number of judicial cases. This issue may be more acute in Iran, where more than fifteen million cases in one year in Iran's judicial courts have been registered (Oji et al., 2023). Needless to say, with the increase in judicial cases, the time required to deal with

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these cases increases due to resources' limitations, especially human resources, and infrastructure (de Oliveira Gomes et al., 2016; Gomes et al., 2017). Obviously, the increase in the delay of the proceedings seriously jeopardizes the administration of justice (Seppälä et al., 2013; Gupta & Bolia, 2024). This is because the prosecution of cases could be weakened by the length of the court process due to reasons such as the loss of evidence and documents, forgetting the facts by witnesses and victims, or even their deaths. In some countries, defendants sometimes confess just to escape from detention centers, which are generally unpleasant and inappropriate places. Hence, the sum of the factors listed can increase the probability of injustice. Therefore, reducing the delay in handling judicial cases by providing a comprehensive schedule for reviewing them according to available resources can bring many advantages (Gupta & Bolia, 2024). In retrospect, it is possible to reduce the number of arrests and increase the probability of a fair trial, which, in addition to increasing psychological and social security, makes other law enforcement organizations, such as the police, who are usually critical of judicial processes, more satisfied (Oji et al., 2023; Gupta & Bolia, 2024).

Clearly, judicial systems in different countries comprise various elements with unique processes. So, it is impossible to provide a general framework for the scheduling of courts for reviewing lawsuits, and this should be done based on a real case study. Therefore, the planning of Iran's judicial system is considered, where lawsuit cases are divided into two categories: 1. family and civil, and 2. criminal (Olyaeei et al., 2020), whose processes are very different, and the present research only examines the family and civil cases. Notably, mathematical models have yet to be used to formulate judicial processes in previous studies, and only a handful of simulation approaches have been employed for such a purpose.

In order to schedule the handling of judicial cases in courts, various considerations significantly distinguish this problem from other scheduling problems. The first challenge is the structuring of the process of judicial cases, which starts with the registration of cases and ends with the execution of rulings. The second challenge is the diversity of lawsuits and their miscellaneous cases, which requires consideration of specialized chambers in courts and judges with different specializations (Sadeghlou & Mohammadi, 2020; Olyaeei et al., 2020; Oji et al., 2023). The next challenge is to consider the review and appeal processes and reflect the frequency of reviewing cases in courts. Also, the requirement to consider the available legal times to register objections to issued sentences that directly impact schedule plans is undeniable. Another crucial consideration is related to the prioritization of lawsuits for processing. In fact, the huge number of cases, on the one hand, and their high diversity, on the other, have forced the Iranian judicial system to prioritize cases based on their importance. Moreover, the permissible waiting time for handling cases and issuing verdicts is another challenge in this context (Sadeghlou & Mohammadi, 2020; Olyaeei et al., 2020; Oji et al., 2023).

Although considering all the mentioned considerations in a planning model can increase the efficiency of such a system, several challenges, such as delays in proceedings, can arise due to mismatches between workload and resources (Ko et al., 2005). Therefore, embedding a sharing system to balance excess capacities in court chambers and their service supply shortages is one of the most effective approaches to mitigate this problematic situation. In this regard, this sharing system needs to work flexibly, where the possibility of assigning a certain number of cases to each court' chamber, more than its capacity is allowable. Therefore, the system can respond to this excess demand through service sharing. On this matter, it is essential to consider a number of characteristics such as unmet demand, net supply balance, maximum sharing capacity, and allowable demand overload (Ko et al., 2005). The last concern, but not the least, is the time required to handle cases in the courts. Undoubtedly, one of the main challenges in court scheduling is the uncertainty at this time. This is because various factors significantly influence the timing, including judges' experience, the completeness of the documents, the availability of litigants and their witnesses, etc. Therefore, the suggested scheduling plans cannot have a high implementation guarantee if such uncertainty is not taken into account (Gunawan & Fathoni, 2023).

According to the literature presented in the next section, no mathematical model has yet been proposed for scheduling judicial cases in courts, let alone the other considerations mentioned. Therefore, a bi-objective mathematical model is developed, with the first objective maximizing service level in the court chambers to ensure that higher-priority cases are handled sooner. Also, the second objective function is to minimize the maximum remaining service capacity in court chambers. In this regard, several considerations, including the types of courts and types of lawsuits, the process according to the type of lawsuits, the variety of cases related to each type of lawsuit, the allocation of judges to court chambers, the allocation of cases to court chambers, the prioritization of cases, the frequency of handling cases, deadline for filing objections, the waiting time to determine a given time to handle cases, permissible time for determining the final verdict of cases, the sharing of services between the chambers of each court, and the uncertainty in the time of handling cases are reflected. In a nutshell, our contributions to the literature are as follows:

- Developing a novel mathematical model for the scheduling of courts for handling lawsuits in Iran's judicial system regarding miscellaneous realistic concerns.
- Prioritizing the handling of different types of lawsuits in specialized chambers of various courts .
- Embedding a judicial service-sharing mechanism among primary courts' chambers to enhance the performance of scheduling plans.

The rest of this paper is organized as follows. An inclusive literature review is provided in Section 2. The problem definition and formulation are proposed in Section 3. The solution approach is explained in Section 4. Case study and computational results are provided in Section 5. Finally, Section 6 provides conclusions and future guidelines.

II. LITERATURE REVIEW

As mentioned in the previous section, compared with other research domains where mathematical models have been used for planning and scheduling processes and operations, a limited number of studies have employed them for planning judicial system operations. Riccio (1974) examined related activities in a court in the form of an analytical model. The presented model could provide insight into how different aspects of a court's activities are functionally related. It could also provide a conceptual basis for a management information system that supported not only day-to-day administrative decisions but also tactical and strategic management control and policymaking. Also, this model could be used for court resource planning. Spurr (1997) used multivariate regression models to estimate the time of handling lawsuits. They stated that the use of expert personnel significantly reduced litigation time and associated financial losses. Kwak et al. (1984) presented a simulation model to evaluate different scheduling procedures for investigating criminal cases, aiming to increase the speed of handling these cases by minimizing interference with court time.

Schniederjans & Hollcroft (2005) presented a goal programming model for selecting jury members of a court in America, where the objective function was to minimize the goals' deviations. These goals included saving the time of the court and the lawyer to select the jury and the impartiality of the jury members from their ideals. Ko et al. (2005) offered a mathematical model for zoning and the location-allocation of facilities to solve the problem of judicial service demand overload for a state court system in the United States. The presented model was designed to optimize decisions such as redistricting service areas, allocating resources to service provider units, and service sharing between service provider units. Also, a meta-heuristic algorithm was proposed to solve the offered model. Alexandra & Dan (2016) used the balanced scorecard method to identify and determine strategic goals and performance criteria of a judicial system. Bray et al. (2016) presented a simulation model for the court scheduling problem. They examined different scheduling policies, such as first-in-first-out for this purpose. The case study for this research was a court in Italy.

Wongsinlatam & Buchitchon (2018) presented an integer programming model for allocating judicial cases to judicial teams in courts. They also proposed two metaheuristic algorithms to solve the model. Giacalone et al. (2020) used a data envelopment analysis model to evaluate the efficiency of the Italian judicial system. Also, they employed multivariable regression models to assess the effects of the court's strategies. Falavigna & Ippoliti (2023) used a data envelopment analysis model to evaluate the efficiency of a court in Italy. They examined this research in two cases: in the first, the input components were related to human resources, while in the second, they were related to judicial costs in court. Azaria et al. (2023) designed and developed measures using the theory of constraints to reduce the time of hearing cases and the number of cases in the hearing queue. Using regression models, Castelliano et al. (2023) studied the effect of employing judges with multiple specialties on reducing the duration of court case reviews in Brazil. The obtained results revealed that handling specialized cases by using these judges increases the efficiency of the court. Lashgari et al. (2025) proposed a bi-objective optimization model that accounts for uncertainty to schedule criminal cases across multiple courts and prosecutors' offices. This model considers a comprehensive array of practical processes and characteristics, such as the organization of judicial cases, the diversity of lawsuits and their associated cases, judges with varying specializations, the prioritization of cases, acceptable waiting times for crime investigations, the completion of investigations, the issuance of indictments, case handling, verdict rendering, and the submission of objections.

A. Research gaps and our contributions

As can be seen, a limited number of studies have been offered for planning and scheduling litigation cases using mathematical models. Also, most of these studies have used simulation models to investigate judicial processes. In addition, the few studies that have employed mathematical models have used data envelopment analysis models to evaluate the efficiency of courts. Therefore, a broad range of concerns has yet to be considered in the domain of the court scheduling problem. So, a new mathematical model is developed to cover these concerns, including structuring the process of handling family and civil cases in Iran's judicial system, where different types of courts with various specialized chambers, including primary, review, and supreme alongside miscellaneous types of lawsuits and their processes. Additionally, the allocation of judges to courts' chambers, the allocation of cases to courts' chambers, the prioritization of cases, the deadline for filing objections, the waiting time to determine a given time to handle cases, the permissible time for determining the final verdict of cases, and the frequency of handling cases are determined. More importantly, an effective sharing system is embedded within the scheduling procedure. Furthermore, two tailored objective functions are offered for this problem: the first maximizes service level in court chambers based on case priorities, and the second minimizes the maximum remaining service capacity in court chambers. Finally, the set-induced robust optimization method is used to address the uncertainty in the timing of case handling. Finally, Table I is provided to illustrate research gaps and our contributions.

III. PROBLEM DEFINITION AND FORMULATION

This research deals with the planning and scheduling of family and civil lawsuits in the Iranian judicial system. The process for dealing with these lawsuits is as follows: first, the petitioner files a lawsuit with the electronic service office. After experts and the referring authority of the judiciary review the documents for the registered request, the requests are sent to the relevant courts' chambers for handling. Since each lawsuit involves a wide range of cases and requires specialized expertise, separate courts with specialized chambers are considered. Therefore, the judges of these courts' chambers have relevant expertise.

According to the nature of lawsuits, three procedures are defined to handle three categories of cases in this system. In the first procedure, some cases for which a final verdict is issued in the primary court cannot be reviewed or appealed. In the second procedure, some cases for which a final verdict is issued in the primary court could be reviewed. In the third procedure, some cases that result in a final verdict in the primary court, in addition to reviews, may also be appealed. As is known, in addition to specialized chambers for each category of lawsuits, there are three types of courts: primary, review, and supreme, all of which have specialized chambers.

Therefore, some cases, such as low-value financial lawsuits, etc., are handled in the primary court, and final decisions are issued and cannot be reviewed. Therefore, this category of lawsuits is sent directly to the execution of the rulings. In cases that can be reviewed, after the primary court decision is issued, their objection can be registered within the prescribed time limit at the electronic judicial offices. Next, they are sent to the general office of the review courts to determine the review chamber, and are processed within the prescribed time. Notably, the financial cases reviewed

Table I. The summarized literature review

Authors and years	Modeling approaches			Decisions						Characteristics										Planning		Environment		Type of cases	
	OR	Analytics/ Regression/ MCDM	Simulation	Planning	Scheduling	Location/ Allocation	Sharing	Efficiency	DO	DTC	PC	Manpower	EJ	SCC	Time limits	DFO	WTH	PTV	FHC	Multi period	Single period	Uncertainty	Certainty	Criminal	Family and civil
Riccio (1974)		✓										✓			✓						✓		✓		
Spurr (1997)			✓		✓	✓						✓									✓	✓			
Kwak et al. (1984)		✓											✓								✓		✓		
Schniederjans & Hollcroft (2005)	✓			✓		✓								✓							✓		✓		
Ko et al. (2005)	✓			✓		✓	✓		✓			✓									✓		✓		
Alexandra & Dan (2016)		✓										✓	✓										✓		
Bray et al. (2016)			✓		✓	✓				✓			✓								✓	✓			
Wongsinlatam & Buchitchon (2018)	✓			✓		✓						✓			✓						✓		✓		
Giacalone et al. (2020)	✓	✓		✓				✓												✓			✓		
Falavigna & Ippoliti (2023)	✓							✓													✓		✓		
Azaria et al. (2023)		✓		✓																	✓		✓		
Castelliano et al. (2023)		✓		✓									✓								✓		✓		
Lashgari et al. (2025)	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓	
Current research	✓			✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓

Operational research (OR); Multiple criteria decision making (MCDM); Demand overload (DO); Different types of cases (DTC); Priority of cases (PC); Expertise of judges (EJ); Specialized courts and chambers (SCC); Deadline for filing objections (DFO), Waiting time to determine a given time to handle cases (WTH), Permissible time for determining a verdict of cases (PTV), and the frequency of handling cases (FHC) cannot be appealed. In other words, the verdicts issued by review courts cannot be appealed. Therefore, this category of cases is sent to the chamber of the primary court that issued the initial verdict to issue the final verdict. Finally, they are sent for the execution of the rulings. However, some non-financial lawsuits, such as lineage and divorce, that have been reviewed can be appealed. Therefore, these lawsuits are examined by the supreme court's chambers within the prescribed time. If the decisions issued by the courts' chambers comply with the law, they are sent to the primary courts' chambers that issued the initial verdicts to finalize them. Finally, they are sent for the execution of the rulings.

Due to the variety of lawsuits in Iran's judicial system and the limited number of human resources, the planning and scheduling process is very complex and challenging. So, a number of considerations are reflected to increase the efficiency of this system. One of them is prioritizing cases so that those with higher priority are handled faster in the courts' chambers. In other words, they are not placed in a queue, and a time is allocated to deal with them. Because family and civil cases are sent directly to the relevant primary courts' chambers after registration, they are handled within a reasonable time by the courts based on their priority. Moreover, a sharing mechanism is considered to share the required services between each court's chambers. In this way, service sharing occurs between chambers with excess service and excess demand. In this regard, the maximum service capacity of the chambers is utilized, and all cases are handled within their cycle. Notably, sharing occurs only between chambers with similar expertise and those belonging to the same court. Fig. 1 presents the handling process for civil and family cases. Also, the main assumptions considered to formulate the explained problem are as follows:

- There is uncertainty in the handling time of cases in the primary, review and supreme courts.
- The service capacity in the chambers of the primary court is limited.
- All chambers of primary courts have a limited overall capacity.
- Service sharing is only performed among the chambers of primary court.
- Each primary, review, and supreme court has specialized chambers.
- Each primary, review, and supreme court has a permissible time for issuing a verdict of cases.
- The maximum waiting time for determining a handling time for the cases is a predetermined number.

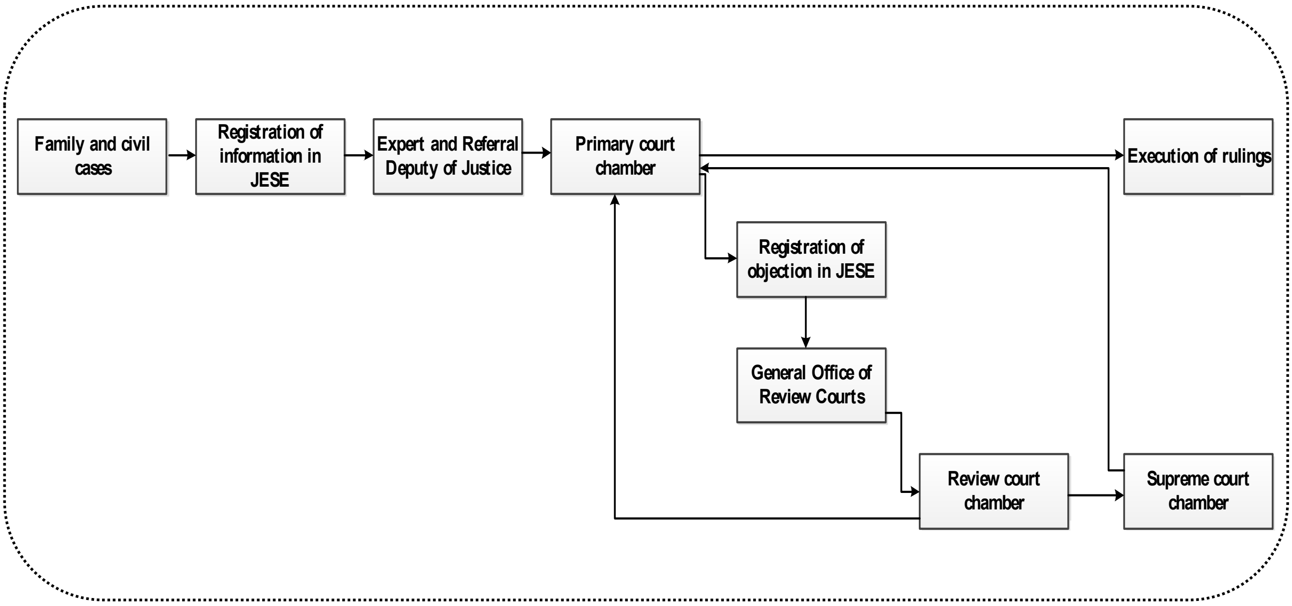

Fig .1. The structure of the handling process of civil and family cases

A. Sets and indices

S	Set of lawsuits, including family and civil $s \in S$
P	Set of all subjects of cases (cheque return, claim for veterans' compensation, marriage portion, divorce, etc.) $p \in P$
P_S	A subset of cases belonging to the lawsuit of type s $p \in P_S$
O	Set of all cases $o \in O$
O_P	Subset of cases belonging to subject p $o \in O$
$O^{\circ}{}_P$	Subset of cases from subject p for which a final judgment is issued in the primary court and cannot be reviewed or appealed $o \in O^{\circ}{}_P$
O'_P	Subset of cases from subject p that can be reviewed $o \in O'_P$
O''_P	Subset of cases from subject p that can be appealed in addition to review $o \in O''_P$
A	Set of judicial electronic services offices (JESEs) $a \in A$
D	Set of justice referral deputy $d \in D$
I	Set of chambers of primary court $i, i' \in I$
I_S	Subset of primary court chambers that is capable of handling lawsuit s $i, i' \in I_S$
N	Set of general office of review courts (GORCs) $n \in N$
J	Set of chambers of review court $j \in J$
J_S	Subset of review court chambers that is capable of handling lawsuit s $j \in J_S$
R	Set of chambers of supreme Court $r \in R$
K	Set of chambers of execution of rulings $k \in K$
C	Set of judges $c \in C$
C_p:	Subset of judges who can handle case p
T	Set of time periods $t \in T$

B. Parameters

V_{oa}^{t}	1 if case o is registered in JESE a in period t; 0 otherwise
L_{pi}^{max}	Maximum service capacity in primary court chamber i to handle cases of subject p
η_o	Importance of case o for prioritization
μ_p	Allowed demand surplus for the cases of subject p
σ_p	Maximum service capacity in all chambers to handle the cases of subject p
de	Time period length (30 days)
$\hat{\varphi}_{oi}$	Duration per day required to handle case $o \epsilon O_p$ by primary court chamber i
$\beta^{'}$	Duration per day to register an objection
$\hat{\lambda}_{oj}$	Duration per day required to handle case $o \epsilon O'_p \cup O''_p$ by review court chamber j
$\hat{\Omega}_o$	Duration per day required for the re-examination and issuance of the final verdict of case $o \epsilon O'_p \cup O''_p$
$\hat{\theta}_{or}$	Duration per day required to handle case $o \epsilon O''_p$ by Supreme Court chamber r
τ_p	Maximum waiting time for determining a handling time for the cases of subject p in the primary court
α_p	Permissible time for issuing a verdict of the cases of subject p in the primary court
β	Deadline for filing an objection
γ_p	Permissible time for issuing a verdict of the cases of subject p in the review court
π_p	Permissible time for issuing a verdict of the cases of subject p in the Supreme Court

C. Decision variables

u_{pad}^{t}	Number of p-type cases sent from JESE a to justice referral deputy d in period t
x_{pdi}^{t}	Number of p-type cases sent from justice referral deputy d to primary court chamber i in period t
g_{pi}^{t}	Number of handled p-type cases in primary court chamber i in period t

f_{pi}^{t}	Service balance for p-type cases in chamber i and period t before service transfer; $\left(f_{pi}^{t}\right)^{+} = \max\{0, f_{pi}^{t}\}$ and $\left(f_{pi}^{t}\right)^{-} = \min\{0, f_{pi}^{t}\}$
vs_{i}	1 if $f_{pi}^{t} > 0$; 0 otherwise
$h_{pii'}^{t}$	Service transfer from chamber i to chamber i' in the primary court to handle p-type cases in period t; $\left(h_{pii'}^{t}\right)^{+} = \max\{0, h_{pii'}^{t}\}$ and $\left(h_{pii'}^{t}\right)^{-} = \min\{0, h_{pii'}^{t}\}$ for $i \neq i'$
zm_{pi}^{t}	Extra service for p-type cases in chamber i and period t after transfer of services
q_{pik}^{t}	Number of p-type cases sent to chamber k of execution of rulings in period t with the issuance of a final verdict by chamber i of the primary court
z_{pia}^{t}	Number of p-type cases for which a temporary verdict was issued in primary court chamber i and their request for review is registered in JESE a in period t
qm_{pan}^{t}	Number of p-type cases sent from JESE a to GORC n for review in period t
pc_{pnj}^{t}	Number of p-type cases sent from GORC n to review court chamber j in period t
tq_{pji}^{t}	Number of p-type cases for which a final verdict has been issued in review court chamber j and sent to primary court chamber i in period t
tc_{pjr}^{t}	Number of p-type cases that can be appealed and are sent from review court chamber j to Supreme Court chamber r
zy_{pri}^{t}	Number of p-type cases sent from supreme court chamber r to primary court chamber i in period t for the issuance of final verdict
ET_{oi}	Time of issuing the initial verdict for case $o \epsilon O'_{p} \cup O''_{p}$ in primary court chamber i
FT_{oi}	Time to complete the handling of case $o \epsilon O^{\circ}_{p}$ in primary court chamber i
RT_{oj}	Time to complete the handling of case $o \epsilon O'_{p}$ in review court chamber j
DT_{or}	Time to complete the handling of case $o \epsilon O''_{p}$ in Supreme Court chamber r
w_{oi}^{t}	1 if case o is assigned to chamber i in period t; 0 otherwise
y_{ci}	1 if judge c is assigned to chamber i; 0 otherwise
nl_{oa}^{t}	1 if case $o \epsilon O'_{p} \cup O''_{p}$ is registered in JESE a in period t for handling; 0 otherwise
l_{or}^{t}	1 if the appeal of case $o \epsilon O''_{p}$ is assigned to supreme Court chamber r in period t; 0 otherwise
wt_{oji}^{t}	1 if case $o \epsilon O'_{p}$ is sent from review court chamber j to primary court chamber i in period t after the review court chamber has issued the final verdict; 0 otherwise

wz_{ori}^{t} 1 if case $o \epsilon O''_p$ is sent from supreme court chamber r to primary court chamber i in period t; 0 otherwise

D. Mathematical model

$$\max z_1 = \sum_{o\epsilon O_p} \sum_{p\epsilon P_s} \sum_{i\epsilon I_s} \sum_{s\epsilon S} \sum_{t\epsilon T} \eta_o \frac{w_{oi}^{t}}{t} \tag{1}$$

$$min\ z_2 = \max\left(zm_{pi}^{t}\right) \qquad \forall\ p\epsilon P_s\ , i\epsilon I_s\ , s\epsilon S\ , t\epsilon T \tag{2}$$

$S.t.$

$$\sum_{o\epsilon O_p} V_{oa}^{t} = \sum_{d\epsilon D} u_{pad}^{t} \qquad \forall\ p\epsilon P_s\ , s\epsilon S\ , a\epsilon A\ , t\epsilon\{1\} \tag{3}$$

$$\sum_{a\epsilon A} u_{pad}^{t} = \sum_{i\epsilon I_s} x_{pdi}^{t} \qquad \forall\ d\epsilon D\ , p\epsilon P_s\ , s\epsilon S\ , t\epsilon\{1\} \tag{4}$$

Objective function (1) maximizes the service level in the court chambers so that the cases that have a higher priority are handled sooner. Also, objective function (2) minimizes the maximum remaining service capacity in court chambers. Constraint (3) indicates the cases registered in JESEs. Constraint (4) indicates the cases referred to the chambers of primary court from the deputy of judicial referral.

$$\sum_{d\epsilon D} x_{pdi}^{t} = \sum_{o\epsilon O_p} \sum_{t'\geq t}^{t+\tau_p-\alpha_p} w_{oi}^{t'} \qquad \forall\ p\epsilon P_s\ , s\epsilon S\ , i\epsilon I_s\ , t\epsilon\{1\} \tag{5}$$

$$\sum_{i\epsilon I_s} \sum_{p\epsilon P_s} \sum_{s\epsilon S} \sum_{t\leq\tau_p-\alpha_p} w_{oi}^{t} = 1 \qquad \forall\ o\epsilon O_p \tag{6}$$

$$\sum_{o\epsilon O_p} w_{oi}^{t'} \leq \left(1+\mu_p\right) g_{pi}^{t} \qquad \forall\ i\epsilon I_s\ , p\epsilon P_s\ , s\epsilon S\ , t' \leq \tau_P\ , t = t' + \alpha_P \tag{7}$$

$$\sum_{i\epsilon I_s} g_{pi}^{t} \leq \sigma_p \qquad \forall\ p\epsilon P_s\ , s\epsilon S\ , t \leq \tau_p \tag{8}$$

Constraint (5) indicates the number of cases sent to each chamber of the primary court and the processing cycle of each case. Constraint (6) ensures that each case is handled by only one chamber of the primary court and within the permissible time. Constraint (7) indicates that the number of cases assigned to each chamber of the primary court is calculated based on the amount of service provided by each chamber and the allowed demand surplus. Constraint (8) ensures that the number of cases handled by all chambers of the primary court cannot exceed the maximum service capacity.

$$g_{pi}^{t} \leq L_{pi}^{max} \qquad \forall\ i\epsilon I_s\ , p\epsilon P_s\ , s\epsilon S\ , t \leq \tau_p \tag{9}$$

$$f_{pi}^{t} = g_{pi}^{t} - \sum_{o\epsilon O_p} w_{oi}^{t'} \qquad \forall\ i\epsilon I_s\ , p\epsilon P_s\ , s\epsilon S\ , t \leq \tau_p\ , t' = t - \alpha_p \tag{10}$$

$$zm_{pi}^{t} = f_{pi}^{t} - \sum_{i' \epsilon I_S} h_{pii'}^{t} \qquad \forall \ p\epsilon P_s \ , i\epsilon I_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{11}$$

$$\left(f_{pi}^{t}\right)^{+} \ge f_{pi}^{t} \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \tag{12}$$

$$\left(f_{pi}^{t}\right)^{-} \le f_{pi}^{t} \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \tag{13}$$

$$\left(f_{pi}^{t}\right)^{+} \le \sigma_p . vs_i \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \tag{14}$$

$$\left(f_{pi}^{t}\right)^{-} \ge \sigma_p . (vs_i - 1) \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \tag{15}$$

$$\left(f_{pi}^{t}\right)^{+} = f_{pi}^{t} - \left(f_{pi}^{t}\right)^{-} \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \tag{16}$$

Constraint (9) guarantees that the number of handled cases by each chamber of the primary court cannot exceed the maximum service capacity of that chamber. Constraint (10) indicates the net balance of service supply in each chamber of the primary court before service sharing. Constraint (11) shows the number of unhandled cases in each chamber of the primary court using the net balance and overall transfer of service to that chamber. Constraints (12) and (13) ensure that $\left(f_{pi}^{t}\right)^{+}$and $\left(f_{pi}^{t}\right)^{-}$ have the correct signs. Constraints (14) and (15) ensure that only one of $\left(f_{pi}^{t}\right)^{+}$and $\left(f_{pi}^{t}\right)^{-}$can be non-zero. Constraint (16) shows the upper limit in service transfer.

$$\sum_{i' \epsilon I_s} \left(h_{pii'}^{t}\right)^{+} \le \left(f_{pi}^{t}\right)^{+} \qquad \forall \ i\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{17}$$

$$\left(f_{pi}^{t}\right)^{+} \ge \left(h_{pii'}^{t}\right)^{+} \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{18}$$

$$\left(f_{pi}^{t}\right)^{-} \le \left(h_{pii'}^{t}\right)^{-} \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{19}$$

$$h_{pii'}^{t} + h_{pi'i}^{t} = 0 \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{20}$$

$$h_{pii'}^{t} = 0 \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{21}$$

$$\left(h_{pii'}^{t}\right)^{+} \ge h_{pii'}^{t} \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{22}$$

$$\left(h_{pii'}^{t}\right)^{-} \le h_{pii'}^{t} \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{23}$$

$$\left(h_{pii'}^{t}\right)^{+} \le L_{pi}^{max} \qquad \forall \ i\epsilon I_s \ , i'\epsilon I_s \ , p\epsilon P_s \ , s\epsilon S \ , t \le \tau_p \ ; i \ne i' \tag{24}$$

Constraint (17) guarantees that the total service transferred for handling cases from each chamber to other chambers cannot exceed the maximum transfer capacity of that chamber. Constraints (18) and (19) ensure that service transfer for handling cases is performed only from chambers with additional service capacity. Constraint (20) indicates that transfers between two chambers of the primary court must have the correct sign. Constraint (21) prevents the transfer of service from one chamber to itself. Constraints (22) and (23) ensure that $\left(h_{pii'}^{t}\right)^{+}$ and $\left(h_{pii'}^{t}\right)^{-}$ have the correct signs. Constraint (24) guarantees that services transferred from a chamber of the primary court cannot exceed the maximum capacity of that chamber.

$$w_{oi}^{t} \leq y_{ci} \qquad \forall\ o\epsilon O_p \ ,i\epsilon I_s \cup J_s \ ,p\epsilon P_s \ ,c\epsilon C_p \ ,s\epsilon S \ ,t \leq \tau_p \tag{25}$$

$$\sum_{i\epsilon I_s \cup J_s} y_{ci} = 1 \qquad \forall\ c\epsilon C_p \ ,p\epsilon P_s \ ,s\epsilon S \tag{26}$$

$$\sum_{c\epsilon C_p} y_{ci} = 1 \qquad \forall\ i\epsilon I_s \cup J_s \ ,p\epsilon P_s \ ,s\epsilon S \tag{27}$$

$$\sum_{o\epsilon O^{\circ}_{p}} w_{oi}^{t'} = \sum_{k\epsilon K} q_{pik}^{t} \qquad \forall\ i\epsilon I_s \ ,p\epsilon P_s \ ,s\epsilon S \ ,t \leq \tau_p \ ,t' = t - \alpha_p \tag{28}$$

$$\sum_{o\epsilon O'_p} \sum_{j\epsilon J_s} wt_{oji}^{t} + \sum_{o\epsilon O''_p} \sum_{r\epsilon R} wz_{ori}^{t} = \sum_{k\epsilon K} q_{pik}^{t} \qquad \forall\ i\epsilon I_s \ ,p\epsilon P_s \ ,s\epsilon S \ ,t \geq \alpha_p + \beta + \gamma_p \tag{29}$$

Constraint (25) guarantees that a case is assigned to a chamber if a judge with appropriate expertise for the type of case is already assigned to the chamber. Constraint (26) guarantees that each judge is assigned to only one chamber. Constraint (27) ensures that each chamber is assigned to only one judge to handle p-type case. Constraint (28) indicates that cases that cannot be reviewed or appealed are sent to the execution of rulings within the permissible cycle after issuing the final verdict of the primary court. Constraint (29) indicates that cases sent from the review and Supreme Courts to the primary court are ultimately executed.

$$\sum_{o\epsilon O'_p \cup O''_p} w_{oi}^{t'} = \sum_{a\epsilon A} z_{pia}^{t} \qquad \forall\ i\epsilon I_s \ ,p\epsilon P_s \ ,s\epsilon S \ ,t'\epsilon T \ ,t = t' + \alpha_p + \beta \tag{30}$$

$$\sum_{i\epsilon I_s} z_{pia}^{t} = \sum_{o\epsilon O'_p \cup O''_p} nl_{oa}^{t} \qquad \forall\, a\epsilon A \ ,p\epsilon P_s \ ,s\epsilon S \ ,t \geq \alpha_p + \beta \tag{31}$$

$$\sum_{a\epsilon A} \sum_{p\epsilon P_s} \sum_{s\epsilon S} \sum_{t\epsilon T} nl_{oa}^{t} = 1 \qquad \forall\ \ o\epsilon O'_p \cup O''_p \tag{32}$$

$$\sum_{o\epsilon O'_p \cup O''_p} nl_{oa}^{t} = \sum_{n\epsilon N} qm_{pan}^{t} \qquad \forall\ a\epsilon A \ ,p\epsilon P_s \ ,s\epsilon S \ ,t \geq \alpha_p + \beta \tag{33}$$

$$\sum_{a\epsilon A} qm_{pan}^{t} = \sum_{j\epsilon J_s} pc_{pnj}^{t} \qquad \forall\ p\epsilon P_s \ ,s\epsilon S \ ,n\epsilon N \ ,t \geq \alpha_p + \beta \tag{34}$$

$$\sum_{n\epsilon N} pc_{pnj}^{t} = \sum_{o\epsilon O'_p \cup O''_p} w_{oj}^{t'} \qquad \forall\ p\epsilon P_s \ ,j\epsilon J_s \ ,s\epsilon S \ ,t \geq\ \alpha_p + \beta \ ,t' = t + \gamma_p \tag{35}$$

$$\sum_{o\epsilon O'_p} w_{oj}^t = \sum_{i\epsilon I_s} tq_{pji}^t \qquad \forall\ p\epsilon P_s \quad, j\epsilon J_s \quad, s\epsilon S \quad, t\epsilon T \tag{36}$$

Constraint (30) indicates that the cases that can be reviewed and appealed, and their objections are registered in JESEs within the permissible time. Constraint (31) indicates the cases that are filed in JESEs. Constraint (32) ensures that every reviewable case is filed in a JESE. Constraint (33) indicates the flow balance between the number of cases registered in each JESE and the number of cases sent to GORCs. Constraint (34) indicates the flow balance of cases sent to the chambers of review court. Constraint (35) indicates the number of cases sent to each review court chamber and their handling cycle. Constraint (36) indicates that cases that cannot be appealed and their re-examination are within the jurisdiction of the chambers of review court, which returns them to the primary court chambers to issue a final verdict.

$$tq_{pji}^t = \sum_{o\epsilon O'_p} wt_{oji}^t \qquad \forall\ j\epsilon J_s \quad, p\epsilon P_s \quad, i\epsilon I_s \quad, s\epsilon S \quad, t\epsilon T \tag{37}$$

$$wt_{oji}^t \leq w_{oi}^{t'} \qquad \forall\ o\epsilon O'_p \quad, p\epsilon P_s \quad, j\epsilon J_s \quad, i\epsilon I_s \quad, t\epsilon T \quad, t' \leq t - \gamma_p - \alpha_p - \beta \tag{38}$$

$$\sum_{o\epsilon O''_p} w_{oj}^t = \sum_{r\epsilon R} tc_{pjr}^t \qquad \forall\ j\epsilon J_s \quad, p\epsilon P_s \quad, s\epsilon S \quad, t\epsilon T \tag{39}$$

$$\sum_{j\epsilon J_s} tc_{pjr}^t = \sum_{o\epsilon O''_p} L_{or}^t \qquad \forall\ p\epsilon P_S \quad, s\epsilon S \quad, r\epsilon R \quad, t\epsilon T \tag{40}$$

$$\sum_{o\epsilon O''_p} L_{or}^t = \sum_{i\epsilon I_s} zy_{pri}^{t'} \qquad \forall\ r\epsilon R \quad, p\epsilon P_s \quad, s\epsilon S \quad, t\epsilon T \quad, t' = t + \pi_p \tag{41}$$

$$zy_{pri}^t = \sum_{o\epsilon O''_p} wz_{ori}^t \qquad \forall\ r\epsilon R \quad, p\epsilon P_s \quad, i\epsilon I_s \quad, s\epsilon S \quad, t \geq \alpha_p + \beta + \gamma_p + \pi_p \tag{42}$$

Constraint (37) indicates the connection between the cases sent from the chambers of the review court to the chambers of the primary court. Constraint (38) ensures that every case, after review by the chambers of the review court, is returned to the chamber of the primary court that issued the first verdict. Constraint (39) indicates the flow balance of the cases that can be appealed after the decision of the review court, and are sent to the chambers of the Supreme Court. Constraint (40) indicates the connection between the cases sent from the chambers of the review court to the chambers of the Supreme Court. Constraint (41) indicates the cycle of completing the handling of cases by the chamber of the Supreme Court and sending them to the chambers of the primary court. Constraint (42) indicates the connection between the cases sent from the chambers of the Supreme Court to the chambers of the primary court.

$$wz_{ori}^t \leq w_{oi}^{t'} \qquad \forall\ r\epsilon R \quad, i\epsilon I_s \quad, o\epsilon O''_p \quad, p\epsilon P_s \quad, s\epsilon S \quad, t\epsilon T \quad, t' \leq t - \left(\alpha_p + \beta + \gamma_p + \pi_p\right) \tag{43}$$

$$FT_{oi} \geq (t.de).w_{oi}^t + \hat{\varphi}_{oi} - M.(1 - w_{oi}^t) \qquad \forall\ o\epsilon o^{\circ}_p \quad, p\epsilon P_s \quad, i\epsilon I_s \quad, s\epsilon S \quad, t\epsilon T \tag{44}$$

$$ET_{oi} \geq (t.de).w_{oi}^t + \hat{\varphi}_{oi} - M.(1 - w_{oi}^t) \qquad \forall\ o\epsilon O'_p \cup O''_p \quad, p\epsilon P_s \quad, i\epsilon I_s \quad, s\epsilon S \quad, t\epsilon T \tag{45}$$

$$RT_{oj} \geq ET_{oi} + \beta' + \hat{\lambda}_{oj} + \hat{\Omega}_o - M.\left(1 - w_{oj}^t\right) \qquad \forall \ o\epsilon O'_p \ ,p\epsilon P_s \ ,j\epsilon J_s \ ,s\epsilon S \ ,t\epsilon T \tag{46}$$

$$DT_{or} \geq ET_{oi} + \beta' + \hat{\theta}_{or} + \hat{\Omega}_o - M.(1 - L_{or}^t) \qquad \forall \ o\epsilon O''_p \ ,p\epsilon P_s \ ,s\epsilon S \ ,r\epsilon R \ ,t\epsilon T \tag{47}$$

$$u_{pad}^t, x_{pdi}^t, g_{pi}^t, zm_{pi}^t, q_{pik}^t, z_{pia}^t, qm_{pan}^t, pc_{pnj}^t, tq_{pji}^t, tc_{pjr}^t, zy_{pri}^t, ET_{oi}, FT_{oi}, RT_{oj}, DT_{or}, \left(h_{pii'}^t\right)^+, \left(f_{pi}^t\right)^+ \geq 0 \tag{48}$$

$$w_{oi}^t, y_{ci}, nl_{oa}^t, l_{or}^t, wt_{oji}^t, wz_{ori}^t, vs_i \in \{0,1\} \tag{49}$$

$$f_{pi}^t, h_{pii'}^t \in R \tag{50}$$

$$\left(h_{pii'}^t\right)^-, \left(f_{pi}^t\right)^- \leq 0 \tag{51}$$

Constraint (43) ensures that every case, after being handled by the chambers of the Supreme Court, is returned to the chamber of the primary court that issued the first verdict. Constraint (44) indicates the completion time of handling cases for which a final verdict is issued in the primary court. Constraint (45) indicates the time of issuing the first verdict in the primary court chambers for the cases that can be reviewed or appealed. Constraint (46) indicates the completion time of handling cases in the chambers of the review court. Constraint (47) indicates the completion time of handling cases after the opinion of the Supreme Court. Constraints (48)-(51) signify the types of decision variables.

IV. SOLUTION METHOD

As explained earlier, the handling times of cases in the courts, including primary, review, and Supreme, are uncertain, and constraints (44) to (47) include these uncertain parameters. Therefore, applying uncertainty approaches is required to overcome this issue. Also, the developed model is bi-objective, and multi-objective optimization approaches are needed to solve it. In this context, two recent, efficient approaches are employed to address these challenges: the set-induced robust optimization method as an uncertainty approach, and AUGMECON2 as a multi-objective optimization approach.

A. Set-induced robust optimization

Consider the following mathematical model (52), where $\tilde{a}_{im}$, $\tilde{b}_{ij}$, and $\tilde{p}_i$ are uncertain parameters (Gheisariha et al., 2023; Allaei et al., 2024; Rashedi et al., 2025).

$$\max \sum_m c_m x_m + \sum_k d_k y_k$$

$S.t$:

$$\sum_m \hat{a}_{im} x_m + \sum_k \hat{b}_{ik} y_k \leq \hat{p}_i \quad \forall i \tag{52}$$

According to Ben-Tal & Nemirovski (2000) and Bertsimas et al. (2012), they can be styled as follows:

$$\hat{a}_{im} = a_{im} + \xi_{im} \bar{a}_{im} \quad \forall m \in M_i \tag{53}$$

$$\hat{b}_{ik} = b_{ik} + \xi_{ik}\bar{b}_{ik} \quad \forall k \in K_i \tag{54}$$

$$\hat{p}_i = p_i + \xi_{i0}\bar{p}_i \tag{55}$$

where a_{im}, b_{ik}, and p_i are nominal values, and $\bar{a}_{im}$, $\bar{b}_{ik}$, and $\bar{p}_i$ are positive constant perturbations, and ξ_{im}, ξ_{ik}, and ξ_{i0} are random variables representing budget parameters. Accordingly, for each uncertain term with respect to a specific uncertainty set, represented by U, the model attempts to find feasible solutions (Ben-Tal & Nemirovski, 2000). An uncertainty set of this type can also be a box, ellipsoidal, polyhedral, or a combination of these. To this end, the configurations of different uncertainty sets are depicted in Figs. 2 to 4. In these figures, Ψ and Γ are adjustable parameters and J_i is a bounded interval. Notably, the current study applied the box-polyhedral uncertainty set (BPUS) to handle uncertainties in handling times.

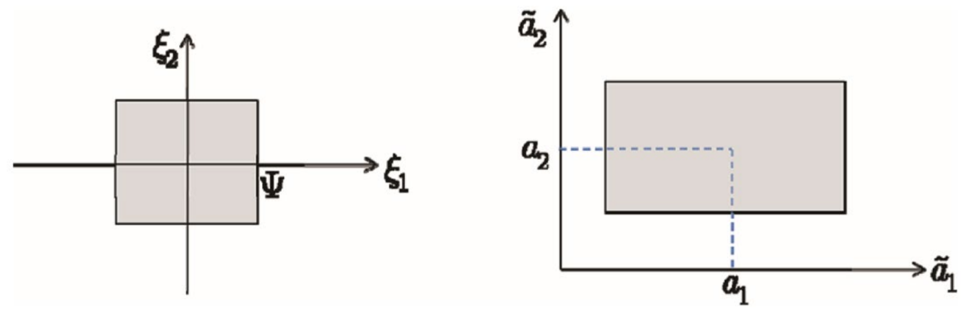

Fig. 2. Box uncertainty set

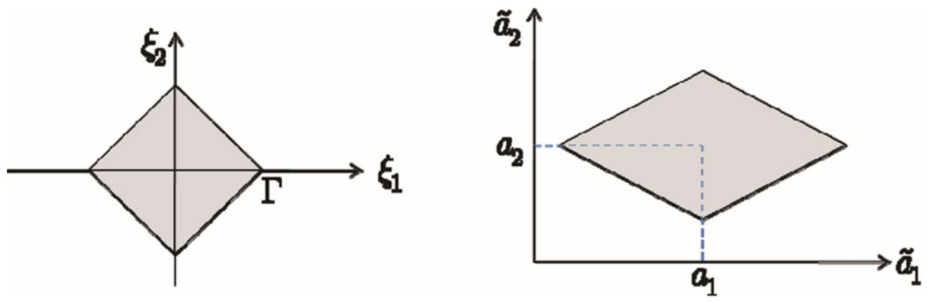

Fig. 3. Polyhedral uncertainty set

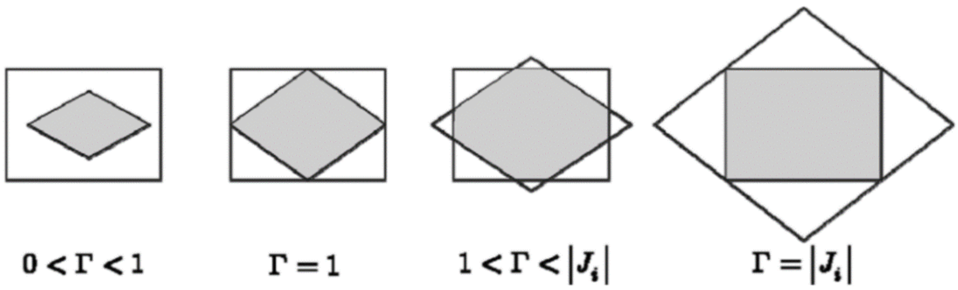

Fig. 4. Box-polyhedral uncertainty set

The subsequent formulation was defined by Zhang et al. (2016) and Ben-Tal & Nemirovski (2000) as the robust counterpart form of constraint (52) once the box-polyhedral form is considered for the uncertainty set and $\Psi = 1$.

$$\sum_{m} a_{im}x_m + \sum_{k} b_{ik}y_k + \left[z_i\Gamma_i + \sum_{m\in M_i} w_{im} + \sum_{k\in K_i} w_{ik} + w_{i0} \right] \leq p_i \tag{56}$$

$$z_i + w_{im} \geq \bar{a}_{im}|x_m| \quad \forall m \in M_i \tag{57}$$

$$z_i + w_{ik} \geq \bar{b}_{ik}|y_k| \quad \forall k \in K_i \tag{58}$$

$$z_i + w_{i0} \geq \bar{p}_i \tag{59}$$

where z_i, w_{im}, w_{ik}, and w_{i0} are auxiliary variables.

Furthermore, in order to eliminate the absolute terms in constraints (57) and (58), u_m and v_k can be applied in the following form as auxiliary variables (Zhang et al., 2016):

$$\sum_{m} a_{im}x_m + \sum_{k} b_{ik}y_k + \left[z_i\Gamma_i + \sum_{m\in M_i} w_{im} + \sum_{k\in K_i} w_{ik} + w_{i0} \right] \leq p_i \tag{60}$$

$$z_i + w_{im} \geq \bar{a}_{im}u_m \quad \forall m \in M_i \tag{61}$$

$$z_i + w_{ik} \geq \bar{b}_{ik}v_k \quad \forall k \in K_i \tag{62}$$

$$z_i + w_{i0} \geq \bar{p}_i \tag{63}$$

$$-u_m \leq x_m \leq u_m \quad \forall m \in M_i \tag{64}$$

$$-v_k \leq y_k \leq v_k \quad \forall k \in K_i \tag{65}$$

When the handling times of cases in constraints (44) to (47) are uncertain, the corresponding robust counterparts of these constraints are given as follows. Notably, the notations of $\mathcal{A}_{oj}$ and $\mathcal{B}_{or}$ are employed to represent the sums of $(\lambda_{oj} + \Omega_o)$ and $(\theta_{or} + \Omega_o)$, respectively.

$$FT_{oi} - z_{oi}^1\Gamma_{oi}^1 - w_{oi}^1 \geq (t.de).w_{oi}^t + \varphi_{oi} - M.(1 - w_{oi}^t) \quad \forall\ o\epsilon O_p\ ,p\epsilon P_s'\ ,i\epsilon I_s\ ,s\epsilon S_2\ ,t\epsilon T \tag{66}$$

$$ET_{oi} - z_{oi}^2\Gamma_{oi}^2 - w_{oi}^2 \geq (t.de).w_{oi}^t + \varphi_{oi} - M.(1 - w_{oi}^t) \quad \forall\ o\epsilon O_p\ ,p\epsilon P_s/\{P_s'\}\ ,i\epsilon I_s\ ,s\epsilon S\ ,t\epsilon T \tag{67}$$

$$RT_{oj} - z_{oj}^3\Gamma_{oj}^3 - w_{oj}^3 \geq ET_{oi} + \beta' + \mathcal{A}_{oj} - M.\left(1 - w_{oj}^t\right) \quad \forall\ o\epsilon O_p\ ,p\epsilon P_s/\{P_s'\}\ ,j\epsilon J_s\ ,i\epsilon I_s\ ,s\epsilon S_2\ ,t\epsilon T \tag{68}$$

$$DT_{or} - z_{or}^4\Gamma_{or}^4 - w_{or}^4 \geq ET_{oi} + \beta' + \mathcal{B}_{or} - M.(1 - L_{or}^t) \qquad \forall\ o\epsilon O_p\ \ ,p\epsilon P_s\ \ ,i\epsilon I_s\ ,s\epsilon S_1\ \ ,r\epsilon R\ \ ,t\epsilon T \tag{69}$$

$$z_{oi}^1 + w_{oi}^1 \geq \bar{\varphi}_{oi} \quad \forall\ o\epsilon \mathring{o}_p\ \ ,p\epsilon P_s\ \ ,i\epsilon I_s\ \ ,s\epsilon S \tag{70}$$

$$z_{oi}^2 + w_{oi}^2 \geq \bar{\varphi}_{oi} \quad \forall\ o\epsilon O'_p \cup O''_p\ \ ,p\epsilon P_s\ \ ,i\epsilon I_s\ \ ,s\epsilon S \tag{71}$$

$$z_{oj}^3 + w_{oj}^3 \geq \bar{\mathcal{A}}_{oj} \quad \forall\ o\epsilon O'_p\ \ ,p\epsilon P_s\ \ ,j\epsilon J_s\ \ ,s\epsilon S \tag{72}$$

$$z_{or}^4 + w_{or}^4 \geq \overline{\mathcal{B}}_{or} \quad \forall\ o\epsilon O''_p\ \ ,p\epsilon P_s\ \ ,s\epsilon S\ \ ,r\epsilon R\ \ ,t\epsilon T \tag{73}$$

B. Multi-objective solution method

Since the offered model is bi-objective, a multi-objective optimization approach is required to solve it. In this regard, decision-makers (DMs) usually employ Pareto-optimal solutions when faced with such problems. It is therefore important to search the solution space to find these solutions. In this regard, a solution is referred to as Pareto optimal if it cannot increase any objective function without decreasing at least one other objective function (Mavrotas, 2009). These solutions then create the Pareto front from which DMs can choose their ultimate preferred compromise. The literature offers a wide variety of methods for resolving multi-objective optimization problems. Among these, AUGMECON2, which was put forth by Mavrotas & Florios (2013), is one of the effective methods. This method is an enhanced variant of the epsilon-constraint approach, wherein the optimization of one objective function (usually the highest priority objective) occurs while the remaining objective functions are considered in terms of constraints as follows:

$$\max\left(f_1(x) + eps \times \left(\frac{s_2}{r_2} + 10^{-1} \times \frac{s_3}{r_3} + \cdots + 10^{-(p-2)} \times \frac{s_p}{r_p}\right)\right)$$

$S.t$:

$$f_k(x) - s_k = e_k \quad k = 2,3,\dots,p; \quad x \in S; \quad s_k \in R^+ \tag{74}$$

where $f_k(x)$, S, and x are objective functions, the solution space, and the decision vector, respectively. In addition, $e_k, r_2, r_3, \dots, r_p$, and s_k represent right-hand side (RHS) values, objective functions' ranges, and surplus variables, respectively. Also, eps is an adequately small number between 10^{-3} and 10^{-6}. According to Ehrgott and Wiecek (2005), the model (74) can have an efficient optimal solution if each of $(p-1)$ objective functions' constraints is required, that is ($s_k = 0$ for $k = 2,3,\dots,p$). Notably, using the full set of RHS values, an optimization model is solved using the primary epsilon-constraint method, in which all objective functions are categorized into predetermined equal intervals. In this regard, AUGMECON2 adopted an acceleration method to eliminate combinations that yield weakly efficient or infeasible solutions.

V. NUMERICAL RESULTS

As explained earlier, the current research is focused on family and civil cases in Iran's judicial system. Therefore, the examined case study is related to one of its judicial complexes. For this purpose, 4 lawsuit subjects have been examined in the form of 40 cases, where case numbers 2, 4, 6, 8, 10, 12, 14, 16, 17, 18, 19, and 20 cannot be reviewed and are handled in the primary court. Also, case numbers 1,3,5,7,9,11,13,15,21,22,23,24,25,26,27,28,29, and 30 can be reviewed, and case numbers 31,32, 33, 34, 35, 36, 37, 38, 39, and 40 can be appealed and are finalized after the decision of the Supreme Court. The proposed models under certain and uncertain conditions are solved by GAMS software with the CPLEX solver. In addition, the values of perturbation level and budget parameters in the uncertain condition, which are employed in the robust optimization approach, are 15% and 85%. The data related to the parameters of the investigated problem are also presented in Table II. It should be noted that the limits of the presented uniform distribution functions are determined based on the data collected from the examined judicial complex. The obtained value of the first objective function under a certain condition is 221 and for the second one is 1. Also, the values of the first and second objective functions are equal to 221 and 3, respectively, in the uncertain condition.

Table II. The values of sets and parameters

Parameters	Values	Parameters	Values
S	2	L_{pit}^{max}	$\sim uniform(1,4)$
P	4	φ_{oi}	$\sim uniform(13,28)$
O	8	λ_{oj}	$\sim uniform(12,22)$
A	1	Ω_o	$\sim uniform(5,12)$
K	1	θ_{or}	$\sim uniform(32,50)$
D	1	τ_p	$\sim uniform(2,4)$
N	1	α_p	$\sim uniform(1,2)$
M	1	γ_p	$\sim uniform(1,2)$
I	4	π_p	$\sim uniform(1,2)$
J	2	ℓ_p	$\sim uniform(2,4)$
R	1	η_o	$\sim uniform(4,10)$
C	6	de	30
		β'	20

Also, Tables III and IV show the details of the obtained solutions in two certain and uncertain conditions. As can be seen, the assignment of each of the cases in each period is determined based on their subject to the primary court chambers. For example, civil cases 2, 8, and 15 are assigned to the 1st chamber of the court in the first period. Also, the number of cases that have been shared between chambers for more effective use of resources is shown in Table III. For example, a case is sent from chamber 4 to chamber 3 with excess capacity in the first planning period. Additionally, this sharing is performed when necessary. For example, there is no need to share services in the certain condition in the third planning period, meaning that the available capacity in the courts' chambers can satisfy their demands. In addition, Table IV shows the completion times for handling cases across all three primary, review, and Supreme courts under certain and uncertain conditions. As shown, the time to handle cases under uncertainty is longer than under certainty. This is because, in the robust optimization method, the model aims to find an optimal solution in the most conservative conditions.

More importantly, to illustrate the differences in case scheduling under certain and uncertain conditions across courts, the relevant Gantt charts are depicted in Figs. 2 and 3. As shown, these Gantt charts for the first planning period provide full details of the assignment and the sequence of case handling. These figures also demonstrate the process by which cases move through different courts. Consequently, the obtained results state that the developed model and solution method are applicable and valid.

Table III. The cases allocated to each chamber of the primary court in each period based on their priorities

Period	Certain					Uncertain				
	Civil		Family			Civil		Family		
	$i1$	$i2$	$i3$	$i4$	Sharing services	$i1$	$i2$	$i3$	$i4$	Sharing services
$T1$	2-8-15	3-7-11-14	19-28-29-31-37	22-27-33	$i4 \rightarrow i3$ 1	2-3-8-15	7-11-14	19-22-28-29-33-37	27-31	$i4 \rightarrow i3$ 2
$T2$	13-10-6-9-16	12	21-24-35-40	26-30-18	$i2 \rightarrow i1$ 1	6-9-10-16	12-13	24-30-35-40	18-21-26	–
$T3$	–	1-5-4	23-25-32-34-38	17-20-36-39	–	–	1-4-5	20-23-25-32-	17-34-36-38-39	–

Table IV. Time of completion of handling (time of final verdict) for civil/family cases

Cases that are handled in the primary court			Cases that are handled after the review court decision			Cases that are handled after the Supreme Court decision		
Cases (O)	Certain	uncertain	Cases (O)	Certain	uncertain	Cases (O)	Certain	uncertain
2	45	49	1	155	169	31	130	149
4	105	108	3	85	99	32	189	206
6	74	79	5	147	162	33	128	144
8	43	47	7	90	100	34	193	207
10	76	78	9	117	125	35	161	177
12	73	77	11	87	98	36	192	201
14	47	52	13	110	128	37	133	141
16	78	79	15	88	95	38	196	209
17	107	111	21	118	128	39	161	173
18	76	78	22	88	100	40	165	173
19	49	50	23	148	158	–	–	–
20	106	111	24	116	129	–	–	–
–	–	–	25	146	158	–	–	–
–	–	–	26	120	137	–	–	–
–	–	–	27	90	95	–	–	–
–	–	–	28	84	93	–	–	–
–	–	–	29	86	100	–	–	–
–	–	–	30	120	127	–	–	–

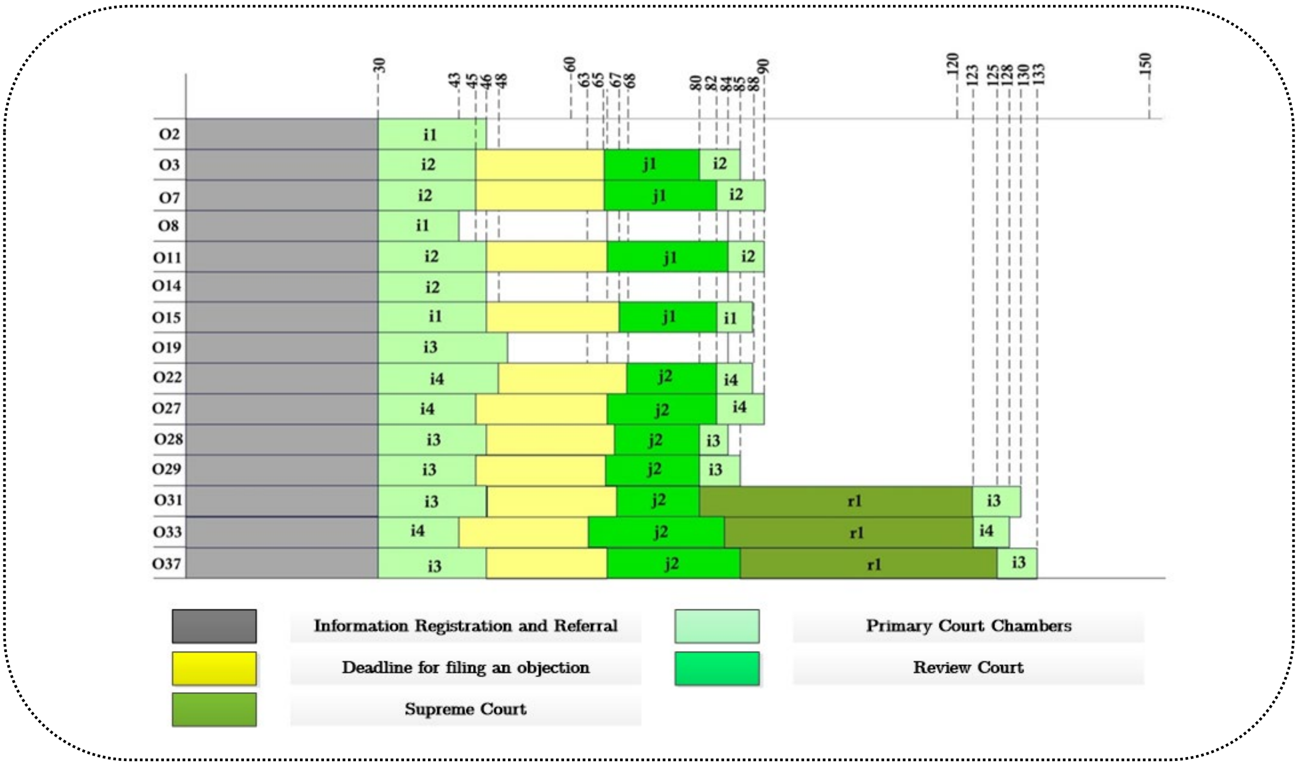

Fig 2. Scheduling of cases under certain condition

Fig 3. Scheduling of cases under uncertain condition

A. Sensitivity analyses

This section presents several sensitivity analyses to illustrate the objective function's behavior with respect to changes in various parameters. In this regard, two critical parameters are considered, including the maximum waiting time for determining a handling time for the cases in the primary court (τ_p) and the maximum service capacity in primary court chambers to handle cases (L_{pi}^{max}). As can be seen in Fig. 4, with an increase in the value of L_{pi}^{max}, the first objective function increases because by increasing the service capacity in each court branch, more cases can be handled in each cycle. As a result, the service level increases due to the enhancement in handling higher-priority cases. It can also be seen that with an increase in the value of τ_p, the first objective function is almost decreasing. It can be seen in Fig. 8 that the second objective function increases with the increase in the value of each of L_{pi}^{max} and τ_p.

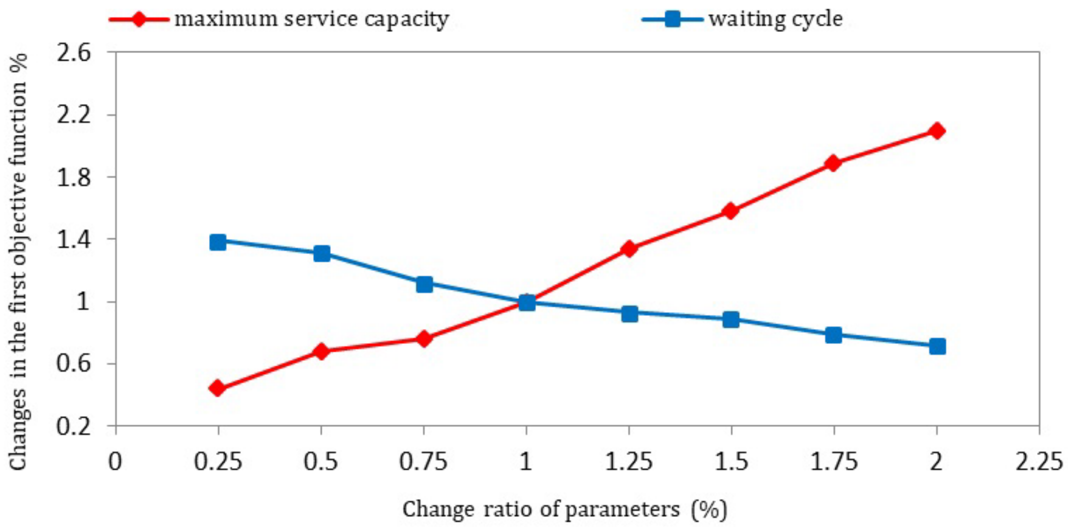

Fig 4. The effect L_{pi}^{max} and τ_p on the first objective function

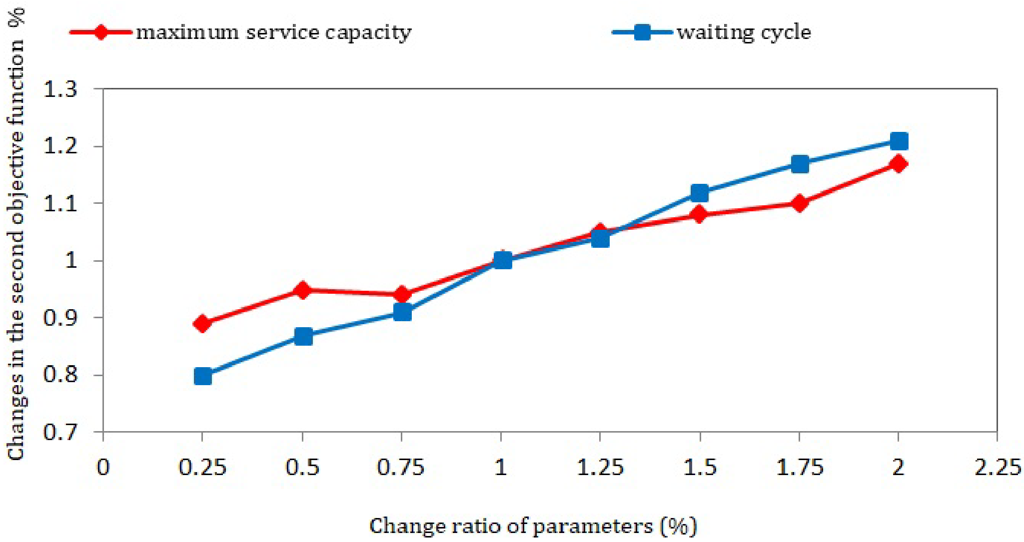

Fig 5. The effect L_{pi}^{max} and τ_p on the second objective function

B. Managerial insights

This section offers two meaningful managerial insights to help decision-makers adopt the best possible measures to increase the system's effectiveness.

Insight 1: Considering the high volume and variety of court cases and their unequal allocation to court chambers on the one hand, and the different experience and ability of judges on the other hand, some court chambers may be facing a lack of service capacity to handle cases. However, some other chambers are facing excess service capacity. This imbalance greatly affects the quality of service and the use of service resources. Therefore, it is necessary to make a decision that has a positive effect on the system performance and increases the level of satisfaction. One of the measures that can be effective is the balance of workload through sharing services between court chambers. This action prevents the loss of service capacity and all cases are handled fairly. In this study, it was found that considering the sharing mechanism reduces 28% excess service capacity.

Insight 2: Some cases must be handled as soon as possible due to their special conditions, and their allowed waiting times for handling are limited. However, due to the high volume of cases on the one hand and the limitation in human resources and court chambers on the other hand, it is impossible to handle all of them in initial cycles. Therefore, to increase justice, the legislature has prioritized handling various lawsuits, and this characteristic is included in the developed model. However, one way to increase prioritization is to increase the number of handling chambers or the service capacity of chambers. It was found that with a 50% increase in the service capacity in the court chambers, the priority increases by 35%. So, the cases with higher importance are handled as soon as possible and in the initial cycles.

VI. CONCLUSION

A novel, multi-period, bi-objective mathematical model was proposed for the planning and scheduling of family and civil cases in Iran's judicial system, wherein three different courts, including primary, review, and supreme, were considered for handling these cases in a real administrative procedure. For this purpose, two tailored objective functions were introduced: the first maximized the service level in court chambers, and the second minimized the maximum remaining service capacity. So as to formulate the procedure of such a system, a broad range of characteristics were reflected to make the model more applicable, such as the diversity of lawsuits and their various cases, specialized chambers in courts, judges with different specializations, filing objections, priority of cases, and permissible waiting time for handling cases and issuing their verdicts. Furthermore, a sharing approach was considered to offer a fair service and balance the workload among court chambers. Moreover, the set-induced robust optimization approach was applied to address the uncertainty in case handling times. The results demonstrated that the proposed model could provide an applicable scheduling plan for cases across different courts. Also, the sharing approach could enhance this plan by better leveraging available resources. Since this study is the first attempt to formulate the court scheduling problem, there are various opportunities to extend the current research. In this regard, the main future direction concerns criminal cases, as their handling differs from that of civil cases. Also, offering exact methods or meta-heuristic algorithms to solve the proposed model in sizable test problems is another interesting direction.

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