A Mixed Integer Linear Programming for Maximizing Effectiveness of Case Assignment in Court of Justice using Metaheuristic Optimization

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Abstract: - It is known that litigation is time consuming. However, justice delayed is justice denied. The effectiveness of judicial system depends on the efficient and timely manner of court case operation. Court case assignment in Thailand is currently operated in a random assignment norm. However, the increasing number of cases in the court of justice contributes as a building block to the reputation of time consuming operating system. Selecting the right cases to be assigned to the available efficient judge in the area is a vital need for judicial operation. Therefore, major challenges with respect to court case assignment are to determine the right case to be assigned to the right efficient judge in the field and to allocate appropriate time for delivering the court decision in order to maximize the effectiveness of the judicial system. In this article, the selected math model is a mixed integer linear programming that is developed to analyze and solve the problem. A metaheuristic algorithm with polynomially bounded computational complexity is proposed to address the issue. Furthermore, results of extensive computational experiments to empirically evaluate its effectiveness to find an optimal solution are reported.

Key-Words: - Justice administration, Case assignment, Mixed integer programming, Assignment problem, Metaheuristic method, NP-hard problem

1 Introduction

Justice administration and case assignment are routine works in judicial system. However, the effectiveness of such work represents as a goal of judicial system which is to ensure the rule of law. The 'rule of law' means that the administration of justice and other exercise of public authority must be predictable and consistent [1].

It is known that litigation is time consuming. The effectiveness of judicial system depends on the efficient and timely manner of court case operation. Court case assignment in Thailand is currently operated in a random assignment norm. However, the increasing number of cases in the court of justice contributes as a building block to the reputation of time consuming operating system. In the last decade, caseload in the court of Thailand has dramatically increased. This is due to the change in constitutional law which requires a full quorum of judges – generally a team of two - to be seated at a hearing.

Several proposals have been made to increase system efficiency including case management, court-annexed mediation, and digital audio testimony recording system [2]. Case assignment is one of the most significant tools in case management to improve efficiency of judicial system. It is proposed in this paper that selecting the right cases to be assigned to the available efficient judge in the area is a vital need for judicial operation. Therefore, major challenges with respect to court case assignment are to determine the right case to be assigned to the right efficient judge in the field and to allocate appropriate time for delivering the court decision in order to maximize the effectiveness of the judicial system.

In mathematics, mathematical modelling transforms the real problem into the objective function with constrained or unconstrained optimization problems to find an exact solution or optimal solution. The mathematical modelling is being used in several fields of science and technology. The objective function is generally being formed in convex programming, nonlinear programming, and stochastic programming. The new trend of objective function is interested in forming the mixed integer linear programming. The mixed integer linear programming (MILP) is popular in the problem of assignment because the objective function of minimize or maximize optimization in MILP is more effective than the linear or nonlinear programming. MILP is a mixed of the several forms of programming which combined the binary integer programming with linear programming.

This research uses the metaheuristic method for assignment problem of the court case and coordination of justice team. The objective of assignment problem includes N cases that must be assigned to N teams where each team has the competence to do all cases. However, due to personal ability, case specification or other reasons, each team may spend different time for minimize or maximize with the objective of assignment problem.

In planning the working system in an organization, the coordination of workers and tasks is a major consideration that reflects the efficiency of the company. The Mixed integer programming (MIP) was used in the examination proctor assignment problem by Takeshi Koide where staffs are assigned for examinations as proctors in the regular examination period [3]. Julia Rieck et al. [4] applied the project scheduling problems subject to general temporal constraints using MILP model and domain-reducing processing techniques. The models used CPLEX 12.1 software to solve lower and upper bounds for resource requirements at particular points in time. David Bredström et al. [5] used MILP model for barge transport planning on the river Rhine. The planning solved the supply chain management of Omya's production of Norwegian high quality calcium carbonate slurry, supplied to European paper manufacturers. Christodoulos A. Floudas [6] applied the scheduling of chemical processing systems based on MILP approaches which improved the computational efficiency in the solution of MILP problems. However, the use of MILP model in juridical problem is still limited.

Metaheuristic optimizations purpose is to find optimal solution for NP-hard problem which solves the local minima problem to find the global minima that solve several practical optimization problems. The algorithm of metaheuristic methods is made of a random number that moves in a wide feasible solution to solve several optimization problem. The metaheuristic method reduces the time in finding the exact solution or the good solution in the problem. Popular methods for assignment problem includes; Ant Colony Optimization (ACO) [7]; Tabu Search (TS) [8]; Particle Swarm Optimization (PSO) [9]; and Firefly Algorithm (FA) [10].

In this paper, the practical problem in juridical area is being used as assignment problem. Selecting the right cases to be assigned to the available efficient judge in the area is a vital need for judicial operation. Therefore, major challenges with respect to court case assignment are to determine the right case to be assigned to the right efficient judge in the field and to allocate appropriate time for delivering the court decision in order to maximize the effectiveness of the judicial system. The objective function is used the MILP optimization model of case analysis and examination. The goal of this proposed model is to maximize the overall effectiveness in identifying the perpetrator of the crime.

The rest of the paper proceeds as follows: Section 2 is an introduction to assignment problem of the case assignment in court of justice. The objective function uses the MILP optimization by using two metaheuristic optimizations. The computational results and discussion about the effectiveness of the proposed metaheuristic algorithms in finding an optimal are provided in Section 3. Finally, section 4 summarizes our conclusions.

2 The Case Assignment in the Court of Justice

2.1 The definition of problem

Nomenclature

C	index set for cases assignment. $\{1,2,...,n\}$
P	index set for justice panel. $\{1,2,...,\mathrm{m}\}$
c	each case assignment. $c \in C$.
μ_c	effective rate for case assignment.
L_c	lower bounds on justice time.
U_c	upper bounds on justice time.
MT	maximum time for justice deadline.
T_{cj}	assignment of case c to the right justice.
X_{ij}	an binary decision variable.

To define the problem, consider the following scenario: A set $C=\{1,2,..,n\}$ of n cases has been filed to the court of justice where a set $P=\{1,2,..,m\}$ of m are available justice panels forming justice teams. If case $c \in C$ is selected for a justice team, at least L_t time units must be spent to deliver the court decision. Also, the maximum amount of time to be spent on each case $c \in C$ must not exceed U_t be time units since spending more than this time would distort justice.

To simplify the presentation of our approach to develop and solve a mathematical model for this problem, the mathematical model that we have adopted assumes that:

- There are fixed numbers of justice panels in one court and one judge can only be in one panel.
- All of the justice panels have the same expertise.
- One case is being assigned to only one panel.
- No interdependencies exist between each case.
- Each case required difference time limit depending on the nature of the case.
- The minimum effective time for delivering a decision for one case is one day. Whereas the maximum effective time for delivering a decision is 90 days which represents the longest time period where a person can be held in prison on remand.

In this paper, the problem is one of finding the assignment of case c to the justice team j. The amount of time $\sum_{c=1}^{n} T_{cj} \le MT$ and the total effectiveness of all cases is maximized and the bound of time, $L_c \le T_{cj} \le U_c$.

2.2 The formulation of problem

The MILP model formulation for the above problem is as follows:

$$\text{maximize } Z=\sum_{i=1}^{n}\sum_{j=1}^{m}\mu_i \cdot T_{ij} \tag{1}$$

Constraints:

$$\sum_{i=1}^{n} T_{ij} \le MT;\ \forall\ j \le m \tag{2}$$

$$T_{ij} - X_{ij} \cdot U_i \le 0;\ \forall\ i \le n, j \le m \tag{3}$$

$$T_{ij} - X_{ij} \cdot L_i \ge 0;\ \forall\ i \le n, j \le m \tag{4}$$

$$\sum_{j=1}^{m} X_{ij} \le 1;\ \forall\ i \le n \tag{5}$$

$$X_{ij} = \begin{cases} 1, & \text{if case } i \text{ is selected to justice } j; \\ 0, & \text{otherwise}; \end{cases}$$
$$\forall\ i \le n,\ j \le m \tag{6}$$

We assume that the effectiveness rate of cases administration are $\mu_1, \mu_2, .., \mu_n$, respectively. The objective function according equation (1) for the above problem is defined to the overall effectiveness of the judicial procedure. The constraint in equation (2) is the total time spent on a sequential of case does not exceed the maximum allowable time MT for each justice team. The constraint of upper bound U_i is the time spent on each selected case i is no more than upper bound in equation (3). The constraint of lower bound L_i is the time spent on each selected case i is no less than lower bound in equation (4) and define X_{ij} as a binary decision variable which let a value of 1 if case i is selected and assigned to justice team j and let a value of 0 if otherwise in constraint according equation (5) and (6). The total number of binary variables is nm and the total number of constrains is $2nm+n+m$.

2.3 Metaheuristic method for problem

The optimization method of maximizing effectiveness of case assignment in court of justice is used two technique metaheuristic method i.e. Firefly algorithm (FA) and Ant Colony Optimization (ACO). The FA technique of metaheuristic algorithms was firstly proposed by Yang in 2008 [11,12]. The FA algorithm is based on the flashing characteristics and behavior of fireflies. The FA is especially used as a metaheuristic technique for solving continuous optimization in

NP-hard problems. Algorithm 1 illustrates the FA pseudo code.

Algorithm 1. Pseudo code of the FA

Define the objective function $f(x)$;
Initialize the firefly population $x = x_1, x_2, \ldots x_n$;
Define the light absorption coefficient γ;
for each firefly x_i in the population **do**
  Initialize light intensity I_i;
end
repeat
  for each firefly x_i in the swarm **do**
    for each other firefly x_j in the swarm **do**
      if $I_i > I_j$ **then**
        Move firefly x_i toward x_j;
      end
        Attractiveness varies
        with distance r via $\exp(-\gamma r)$;
        Evaluate new solutions light and
        update intensity;
    end
  end
  Rank the fireflies and find the current best;
until termination criterion reached;
Rank the fireflies and return the best one;

The second metaheuristic method that is being used in this paper is ACO. Different from the FA, the ACO principles are based on the behaviour of ants [13,14]. Despite the fact that finding the shortest path is not the goal of ants, at the end their achievement is creating the shortest path between their nest and food source. During the commuting between their nest and food source, ants deposit a chemical substance called pheromone on the path. The algorithm of ACO is presented in Algorithm 2.

Algorithm 2. Pseudo code of ACO

Initialize pheromone trials;
while termination criterion
  for each ant **do**
    Construct a solution based on ant
    behavior and pheromone trial;
  end
  Update pheromone trials;
  Apply evaporation strategy;
  Apply reinforcement strategy;
end
Return best found solution;

In applying the method, the cases are assigned to justice panels considering the maximum time available. The cases are sorted into a list with the amount of time allocated for each case. Then the first case in the list is assigned to the justice panel. If the minimum time required for this case is greater than the total time available of the justice team, this case is skipped to the next case in the list. This process is carried out until the total time available for all justice panels is utilized or all cases have been assigned to justices.

2.3.1 The metaheuristic optimization to solve problem

The proposed metaheuristic optimization to solve the problem is described as follows:

Input: Index set of C and P. For each case $c \in C$,effectiveness rate is μ_c and maximum time for justice team deadline is MT. Lower and upper bounds on decision times are L_c and U_c, respectively. Assumption, effectiveness rates for each cases are in a decreasing order ($\mu_1, \mu_2, \ldots, \mu_n$).

Step 1: Set $c = 1$, and set $Z_c^* = T_{ci}^* = 0$, $MT_i = MT$, for each $c \in C$ and $i \in P$.

Step 2: Find justice $i \in P$, and MT_i if $U_c \le MT_i$ then $T_{ci}^* = U_c$ and update $MT_i = MT_i - T_{ci}^*$. Next, go to step 4 and go to step 3 where otherwise.

Step 3: If $L_c \le MT_i$ then $T_{ci}^* = MT_i$ and $MT_i = MT_i - T_{ci}^*$ and go to step 4.

Step 4: If $MT_z = 0$ for all $z \in M$ or $c = n$ then go to step 5. Otherwise, let $c = c + 1$ and loop $= c$ and return go to step 2.

Step 5: Calculate $Z^* = \sum_{c=1}^{n} \mu_c T_{ci}^*$ and stop.

Output: The best solution of total effectiveness is Z^* and T_{ci}^* is the global maximize point of problem used by FA and ACO.

3 Results and Discussion

The computational and effectiveness results are generated using FA and ACO. For empirically evaluating the effectiveness and the efficiency, the workstation used for carrying out the result is equipped with 2.40 GHz processor, 4.00 GB of RAM, and the system used Microsoft 7. Matlab verison R2013b software was used to carry out simulation of the proposed algorithm. The number of cases for experimental parameters was 20, 30 and 50 and the number of justice team for experimental parameters was 3, 4 and 5. The total time available for justice decision is $MT = 90$. Therefore, we generated parameters μ_i, U_i, and L_i by following two problem with a uniform distribution e.t. in from $P1: \mu_i = (1,90), L_i = (1,30), U_i = (1,90)$ and $P2: \mu_i = (1,90), L_i = (1,90), U_i = (1,90)$.

Problem hardness is likely to depend on the values and ranges of the parameters of the problem.

Table 1 shows the total available time (second) in finding an optimal solution and 20 problem instances were generated, which is sufficient to produce steady state empirical result for the measures of performance. Percent deviation is 100*[Optimal solution - FA or ACO solution]/[Optimal solution] and average of percent deviation of 20 instances is $\sum_{i=1}^{20}$ [percent deviation]/20.

Table 1 Comparing the results of FA and ACO for the problem

P	*n*	*m*	FA		ACO	
			Effectiveness		Effectiveness	
			Avg	Time	Avg	Time
P1:	20	3	0.01	103.81	0.61	258.47
		4	0.27	222.88	0.97	331.12
		5	0.13	372.01	0.58	472.56
	30	3	0.52	436.05	0.78	548.01
		4	0.54	554.50	0.82	642.70
		5	0.19	640.51	0.54	714.40
	50	3	0.08	733.30	0.81	812.31
		4	0.04	862.47	0.30	928.27
		5	0.02	918.17	0.35	1005.35
P2:	20	3	0.05	115.97	0.63	218.56
		4	0.02	275.46	0.34	379.35
		5	0.37	393.27	0.58	495.32
	30	3	0.29	458.45	0.52	558.54
		4	0.74	516.37	0.82	696.18
		5	0.19	647.64	0.24	724.64
	50	3	0.13	752.46	0.48	858.51
		4	0.14	853.54	0.62	952.67
		5	0.02	976.25	0.30	1065.64

Two techniques of metaheuristic method are the valid and efficient methods in numeric programming and have been employed due to their strong convergence properties. Specific parameter settings for the algorithms are described in Table 2.

Experimental results show in Table 1 that time of optimal solutions and average of percent deviation for maximize effectiveness of FA are better than those of fast ACO.

In the results, it can be seen that when the number of cases was 20 and the number of justice team was 3 for experimental parameters, P1(20,3), the average of percent deviation of FA is 0.01 and total available time of FA is 103.81 which is better than the fast ACO. Furthermore, in the P2(50,5) the average of percent deviation of FA is 0.02 and total available time of FA is 976.25 which is also better than fast ACO for the measures of performance.

Table 2 Parameter settings for the metaheuristic optimization

Methods	Parameter name	Parameter value
FA	Maximum number of iterations	1000
	Number of Fireflies	20
	Light absorption coefficient	1
	Attraction coefficient base value	2
	Mutation coefficient	0.2
	Mutation coefficient damping ratio	0.98
ACO	Maximum number of iterations	1000
	Number of ants	50
	Initial pheromone	10
	Pheromone exponential weight	0.3
	Evaporation rate	0.1

In this research, in order to maximize the overall effectiveness, a MILP model is used to analyse the problem of allocating optimal time for selected cases and the team of justice panels. The research shows that even the idealized simple version of the sequential problem in administrative law with multiple justice teams is NP-hard. The results of the empirical experiments strongly validate that FA is quite effective in finding an approximately optimal solution to the general problem.

4 Conclusion

In this paper, selecting the right cases to be assigned to the available efficient judge in the area is a vital need for judicial operation. The selected math model is a mixed integer linear programming that is developed to analyze and solve the problem. A metaheuristic algorithm with polynomially bounded computational complexity is proposed to address the issue. The results, simulation experiments are implemented on MILP assignment problem. Experimental results show that time of optimal solutions and average of percent deviation for maximize of FA are better than those of fast ACO. The performance of FA is better than that of ACO for maximizing effectiveness of case assignment in court of justice. In the future work, it will be interesting and useful to conduct empirical and theoretical studies to develop appropriate measures and methodologies to determine the effective time of various types of cases and minimizing the total time of case assignment in court of justice. Moreover, it will be useful to improve metaheuristic optimization for the fast computing and defining parameter optimization for the assignment problem in legal fields.

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