Optimization Method of Project Manager Based on Particle Swarm Optimization Algorithm

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Abstract: Managers are the guarantee of the project. They are good at execution, leadership and management. A good team of managers can greatly improve the efficiency. However, a good team does not mean that a lot of managers are included. On the contrary, too much managers and an unreasonable distribution would led to many problems such as more project costs and overlapping management functions. In existing research, the management structure and personnel allocation only stay in qualitative analysis. No quantitative indicators have been formed, so that the suggestions given can only give optimization directions and it is difficult to give quantitative goals. A novel project manager optimization method based on particle swarm optimization is proposed. Firstly, a manager optimization model, a project exception handling time model and a cost model respectively are established. And then, the number of managers and Job configuration are optimized with the goal of ensuring timely handling of project exceptions and reducing management costs. Finally, a project with four tasks are used as the research object, and the algorithm convergence speed, task cost and number of managers are studied. The results show that the method can consider the working efficiency of managers and management cost comprehensively. With this method, an optimal management combination can be sought.

1 INTRODUCTION

Managers lead employees to practice project goals and values, coordinate employee relations, and deal with emergencies during the completion of project tasks. They are the backbone of the healthy operation of the entire project. Reasonable manager configuration can help the project team run more efficiently, reduce the operating cost of the project and enhance the competitiveness of the enterprise. However, the existing project managers allocation is unreasonable, and there is no effective distribution standard. These problems lead to the overlapping of functions of some managers and low work efficiency.

Ensuring the stable operation of the project while reducing the cost is the purpose of the project (Marnewick 2020). In order to respond to the government's call, various factors should be considered, such as high efficiency (Liu 2020, Daisik 2020), low carbon, and flexibility (Gu 2021). As the backbone of a project, managers are concerned by researchers. In recent years, many researches pay attention to managers. Firstly, to ensure a reasonable project structure, project management model is studied. For example, a collaborative delivery method is proposed by Sina et al (Moradi 2020) and a cooperative management approach by project managers and systems engineers is proposed by Sigal et al (Kordova 2019). Besides, many researchers try to find the relationship between the competence of the project manager and the success of the project. In this aspect, emotional intelligence (Montenegro 2021) and experience (Salvador 2021) are studied. Also, it is necessary to give certain restrictions to the project manager. Thus, the influence of accountability arrangements is studied (Mac 2020). Project managers' influence strategies is also studied (Crowston 2007). At present, improving management mode, enhancing team building and optimizing personnel allocation are the main means to optimize project management. As the project progresses, different businesses and

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departments intersect with each other. This problem leads to a complex management structure and redundant department functions, thereby increasing operating costs and reducing work efficiency. Simplifying the decision-making process by improving the management model and reducing the length of the control chain can help improve work efficiency and reduce operating costs (Aghamolla 2021). With the development of science and technology, the Kanban management model based on big data, the management construction paradigm based on knowledge graph (Lundin 2022) and the model optimization method with human capital (Hamstra 2021) have been widely studied and applied. These technologies have simplified the management structure and achieved good results. However, the original management model of the project is often deeply rooted, and a large-scale change of the management model can easily lead to a decrease in the stability of the existing structure. Enhancing team building if helpful to forming an efficient operation team, promoting the realization of block operation of the project, and realizing multi-point parallel construction to promote the operation of the project (Fang 2022). In the existing team building research, the influence of methods such as gender factor (Keith 2021), abusive management (Varty 2020), and performance management (Zimmermann 2021) are proposed, and reasonable management suggestions are also given. However, this kind of team building is very dependent on the personal ability of the team leader, and the replacement of the leader often leads to the replacement of most of the personnel, thus the long-term stability of the team is difficult to guarantee. Improving the quality of members is an important means to improve project efficiency and reduce costs. At the same time, it is also the basic guarantee for improving the management model. Reasonable managers allocation helps motivate members and effectively deal with project abnormalities. In recent years, managers allocation has gradually been valued by researchers. For example, Johanna Anzengruber et al. examines whether managerial capability fit between line managers, middle managers and top-level managers enhances effectiveness (Anzengruber 2021). Chen et al. analyze the role of staffing in the infrastructure industry. It is not difficult to see that staffing plays an important role in project operation, at the same time it directly determines the quality and efficiency of project completion. However, in the existing staffing research, the management structure and staffing allocation only remain in the qualitative analysis, and there are no quantitative and quantitative indicators. As a result, the suggestions given can only give the optimization direction and it is difficult to give the quantitative target.

Aiming at the existing problems, an optimal allocation method of project managers based on particle swarm algorithm is proposed. First a number of managers and allocation matrix is established. And then, a cost and time management model is built. A particle swarm optimization algorithm with the goal of reducing costs and improving efficiency was constructed, and the project managers allocation suggestions were given. The performance of the algorithm is analyzed by taking a project data as a case.

2 OPTIMAL CONFIGURATION METHOD OF PROJECT MANAGERS

2.1 Particle Swarm Optimization Algorithm

Reasonable optimization criteria and efficient optimization methods are the basic requirements for assigning project managers. The particle swarm optimization algorithm was originally an evolutionary computing technology based on swarm intelligence, inspired by the predation behavior of birds. Like most swarm intelligence optimization algorithms, this algorithm usually initializes a set of solutions (particles) in a random way. Then continuously updates these solutions in an iterative way, so that the entire population is adjusted to a better fitness value as a whole. Finally, it is expected that the optimal solution to the problem can be found within a limited number of iteration steps. Suppose a group of birds randomly search for food in an area with only one piece of food. All birds in the group do not know the location of the food, but they know the distance between their current position and the food. area to search. Its mathematical description is as follows: a swarm of q particles flies at a certain speed in a d-dimensional search space, where, each particle contains three attributes, that is: current position, historical best position and velocity when searching. Assuming that the t-th generation of birds is currently preying on the flock, the i-th particle in the D-dimensional search space can be expressed as

Particle position: $X_i^t = (x_{i1}^t, x_{i2}^t, ..., x_{id}^t)$

Particle velocity: $V_i^t = (v_{i1}^t, v_{i2}^t, ..., v_{id}^t)$

The current individual optimal of the particle: $P_i^t = (p_{i1}^t, p_{i2}^t, ..., p_{id}^t)$

The velocity update formula consists of three parts: inertial motion, cognitive learning and social learning. Relying on individual experience and social learning experience, it guides the flight trajectory of the next generation of particles. The current individual optimum and the current group optimum of each particle in the *t*-th generation are determined by evaluating the fitness value of each particle. Then update the velocity and position of each particle. The specific algorithm is shown in Equation 5 and Equation 6 (Song 2021).

$$V_{id}^{t+1} = \omega V_{id}^t + c_1 r_1 (p_{id}^t - x_{id}^t) + c_2 r_2 (p_{gd} - x_{id}^t) \quad (1)$$

$$x_{id}^{t+1} = x_{id}^t + v_{id}^{t+1} \quad (2)$$

Where, V_{id}^{t+1} is the velocity of the *i*-th particle in the *d*-th dimension during the *t*-th iteration, *i*=1, 2, …, *q* is the *i*-th individual, *q* is the population size, *t*=1, 2, …,t_{max} is the number of iterations, *d*=1, 2, …, *D* is the dimension of the optimization problem, *w* is the inertia weight and its role is to control the influence of the current speed on the back. A larger value of *w* can make the global search ability of the algorithm stronger. Particle swarms explore the entire search space. Conducive to the detection of new advantageous areas. c_1,c_2 is the acceleration factor and its function is to make the particle have self and social cognition ability, usually a positive constant. Contrary to the parameter *w*, the larger the acceleration coefficient, the stronger the local development ability of the algorithm, and the particle swarm will be more inclined to the local optimal position. The parameters c_1 and c_2 interact with the *w* parameter to jointly control the global exploration and local development of the search space by the population. r_1, r_2 is a random number uniformly distributed on [0,1] to maintain the diversity of the population, x_{id}^{t+1} is the current position of the *i*-th particle in the *d*-th dimension during the *t*-th iteration, p_{id}^{t+1} is the position of the *i*-th particle in the *t*-th iteration process of the individual extreme point of the *d*-th dimension and P_{gd} is the position of the best global extreme point searched by the entire particle swarm in the *d*-th dimension so far. In order to prevent particles from moving away from the search space, the velocity *v* of each dimension of the particle is usually limited to the range [-v_{max}, v_{max}]. The choice of v_{max} will affect the global and local search ability of the algorithm. If its value is too large, the particles will fly away from the optimal solution, and if it is too small, it will fall into the local optimal solution. Therefore, v_{max} is generally set as the variation range of each dimension variable without fine selection and adjustment (Feng 2021).

In the PSO algorithm, each generation of particles flies in the direction of the optimal particle according to the experience gt of the group and its own experience pti, that is, the PSO algorithm executes a kind of "conscious" mutation, and the algorithm features is shown as follow.

1) The particles have memory. It can memorize the optimal position (gt) experienced by the entire particle swarm and pass it to other particles.

2) The algorithm has a simple structure and requires fewer parameters to adjust.

3) It does not contain complex operations and is based on particle motion. Complete the search.

4) The particle motion is modified by self-cognition (cognitive learning part) and social cognition (social learning part).

2.2 Managers Layout Optimization Model Establishment

Managers are responsible for project task assignment and abnormal status processing. The management layout optimization model is established to deal with members and task abnormal status in a timely and effective manner. A typical multitasking project structure is shown in Figure 1. The project mainly includes B_1, B_2, … B_n, a total of n tasks, each task has O_1, O_2, ...O_n sub-tasks, and a manager allocate and optimize matrix *M* and *X* are defined as Equation 3 and Equation 4.

$$M = [m_1, m_2, \ldots, m_n](\forall 1 \le k \le n, m_k \le O_k) \quad (3)$$

$$X = \begin{bmatrix} x_1^1 & x_1^2 & \ldots & x_1^{m_1} & O_{o1-m1} \\ x_2^1 & x_2^2 & \ldots & x_2^{m_2} & O_{o2-m2} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ x_n^1 & x_n^2 & \ldots & x_n^{m_n} & O_{oi-mn} \end{bmatrix} (\forall 1 \le K \le n, x_k^{m_k} \le m_k) \quad (4)$$

Where *M* is the vector of the number of managers, m_1 , m_2 ,…, m_n are the main tasks respectively, B_1,B_2,…B_n are the number of managers assigned, *X* is the manager position matrix, x_{ij} is the number of subtasks that the *j*-th manager of the *i*-th business is responsible for.

The two major goals of optimizating the number of managers and the location allocation scheme are reducing the cost of management and improving management efficiency. Suppose that there are *t* exceptions occurring in the subtask during the daily operation. The objective function of the manager's arrangement optimization model can be expressed by Equation 5.

$$\begin{cases} \min M_{sum} = \sum_{1}^{i} m_k \\ \min C_{sum} = \sum_{1}^{t} C_k \end{cases} \quad (5)$$

Where M_{sum} is the sum of project managers, Ck is the exception handling cost of the k-th subtask, and C_{sum} is the total cost of handling abnormal states.

In order to ensure the quality of completion of all project tasks, constraints to set maximum individual management thresholds for each project. The number of tasks assigned should not exceed the corresponding maximum processing threshold (*TOL*) for the project.

$$\begin{cases} x_1^{j_1} \le TOL_1 \\ x_2^{j_2} \le TOL_2 \\ \quad \ldots \\ x_n^{j_n} \le TOL_n \end{cases} (j_k \le m_k) \quad (6)$$

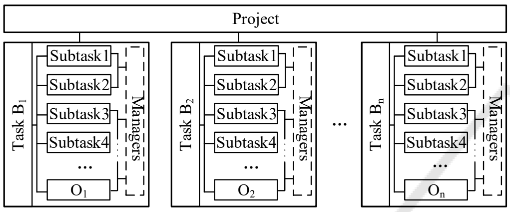


Figure 1: Personnel structure and task allocation of a project.

The optimization method of project managers based on particle swarm optimization is shown in Table 1. The steps include initialization parameter space dimension d, population particle number N, maximum number of iterations *ger*, position parameter limit X_{limit} and speed parameter limit V_{limit}. In the process of iterative, the particle velocity and particle position are updated, the fitness function of the particle is calculated, the current global optimal solution and local optimal solution are updated according to the fitness function. When the number of iterations meets the requirements, the final global optimal solution and local optimal solution are output. A single optimal solution for the sensor layout is finally obtained by analyzing the optimal solution set.

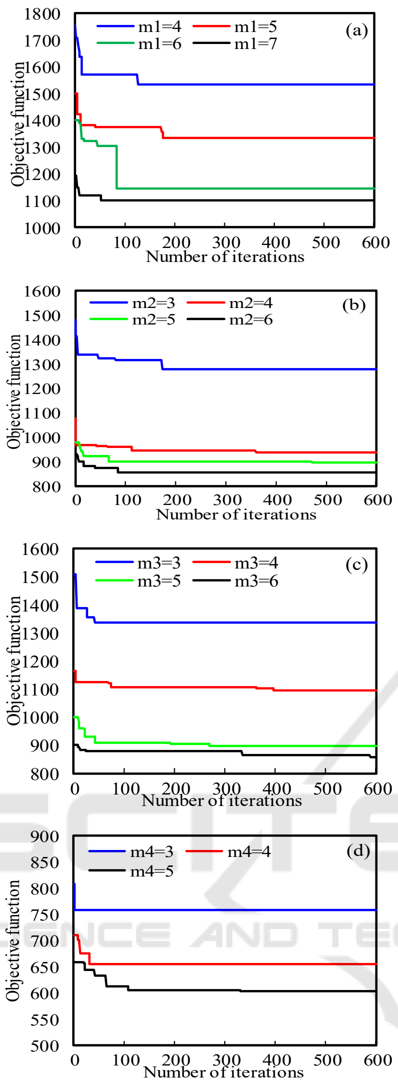
3 CASE STUDY

3.1 Model Building and Optimization Process

A project with four tasks in an enterprise is selected as the research object. In the project, the number of subtasks of each task is 10, 8, 8, 6. Then, the common time for project managers to deal with abnormal events is obtained. When establishing discrete particle swarm optimization, the inertia weight is taken as ω=0.4, the self-learning factor is c_1=0.7, the global learning factor is c_2=0.3, the maximum number of iterations is 600, and the population size is N=8. When the case exceeds the maximum position limit *Xlimit*, a correction algorithm is used to determine and correct the particle position. The managers of each task are assigned to optimize under different numbers of managers. The global optimal solution in the optimization process is recorded. And, the iterative convergence process of the assignment optimization of each task manager is obtained in Figure 2. It can be seen from Figure 2 that the objective function converges to the optimal solution interval when iteratively reaches 200 times, and obtains the optimal solution after iterating to about 400 times. The results show that the particle swarm optimization algorithm with the current optimization parameters has efficient convergence.

Table 1: Managers optimization method based on particle swarm optimization algorithm.

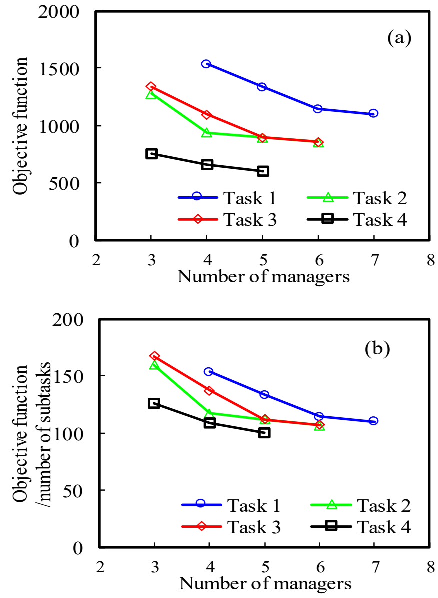
1	**Define** d, N, *ger*, X_{limit}, V_{limit};	5.2	**If** i>ger
2	**Define** ω, c_1, c_2;	5.3	break;
3	**Initialize** *pbest, Gbest*=[$gbest_1$,...,$gbest_N$];		**Else**
4	**Initialize** P_j^1, V_j^1;		comtimue
5	**While** i=1		**Renew** V_j^{i+1};
5.1	$\min M_{sum} = m_1 + m_2 + \ldots + m_i$	5.4	**Renew** P_{i+1} j=P_i j+V_j^{i+1};
	$\min T_{sum} = \sum_1^p T_k$	5.5	**Renew** i=i+1;
	Renew *Gbest*=[$gbest_1$,..., $gbest_N$];	5.6	**end while**
		6	**end**



(a) Task1 (b) Task2 (c) Task3 (d) Task4

Figure 2: Iterative Convergence Process of Assignment Optimization of Each Task Manager.

The allocation of managers for each task project is optimized, and the optimal solution for the allocation of task managers under different number of managers is obtained. The relationship between management cost and the number of managers is shown in Figure 3. It can be seen from Figure 3 (a) that under the same number of managers in the project, task 1 has the highest management cost; task 4 has the lowest management cost, cause the small number of subtasks. Figure 3 (b) shows the optimal solution obtained by the method. This method makes the average cost of sub-tasks of each task of the project basically close and ensures that each sub-task can be effectively managed. At the same time, the method avoids the uneven distribution of resources. Subtasks are over-managed or under-managed.



(a) The total cost of each task management (b) Average management cost of each subtask

Figure 3: Iterative Convergence Process of Assignment Optimization of Each Task Manager.

3.2 Optimal Solution Discussion

The optimal solutions for each task under different numbers of managers are cross-combined to determine the number of task managers, and a total of 192 combinations are obtained. The optimal combination is selected from the total number of different managers, and the total management cost of the project under different managers is shown in Figure 4. It can be seen from Figure 4 that when the number of managers is greater than 19, the effect of increasing managers on the total project cost is no longer significant. When the optimization goal is set to be no higher than 4000 total management costs, the project requires 17 managers. The personnel cost, which increases with the number of people, is modeled as a linear growth. Rather than using the number of people as a constraint, it is more efficient to construct an integrated objective function. The method of constructing the integrated objective function is given by Equation 7.

$$O_i = \omega_1 \frac{C_{man}}{C^*_{man}} + \omega_2 \frac{C_{per}}{C^*_{per}} \quad (7)$$

where there O_i is the value of integrated objective function; ω_1, ω_2 are weight factors (ω_1+ω_2=1), and its value depends on the importance of the two costs in decision-making; C_{man} and C_{per} are represent management costs and personnel costs respectively; C^*_{man} and C^*_{per} represent the dimensionless constants of the corresponding indicators, respectively. The integrated objective function for placing orders with different weight factors is given in Figure 5. Under the conditions of C^*_{man} =1000, C^*_{per} =18000, ω_1 =0.5, ω_2=0.5, the objective function O_i reaches the minimum when the number of managers is 19. That is, under the goal of balancing management costs and personnel costs, the optimal number of managers is 19.

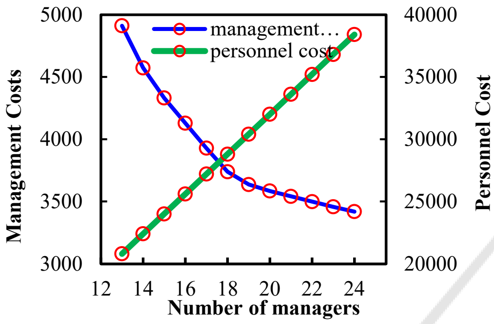


Figure 4: The relationship between the total management expenditure and the number of managers.

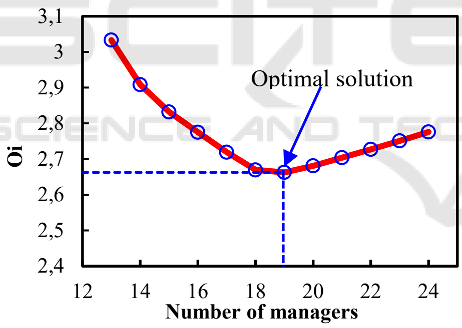


Figure 5: The integrated objective function for placing orders with different weight factors.

At the same time, the distribution of the objective function under different weight assignments is also studied. The trend of oi under different values of ω_1 and ω_2 is shown in Figure 6. It can be seen that the trend and extreme value of the objective function can change with the weight factor. In the extreme case when the weight distribution is ω_1 =0.1, ω_2=0.9, the objective function is monotonically increasing. The strategies that minimize personnel costs are selected as the optimal solutions. In the scheme discussed again, the optimal solution is when the number of managers is 13. On the contrary, when the weight distribution is ω_1 =0.9, ω_2=0.1, the objective function is monotonically increasing. The strategies that minimize personnel costs are selected as the optimal solutions. In the scheme discussed again, the optimal solution is when the number of managers is 24. Therefore, in some management-oriented and personnel-oriented tasks, decision makers can reasonably adjust the weights based on expert experience.

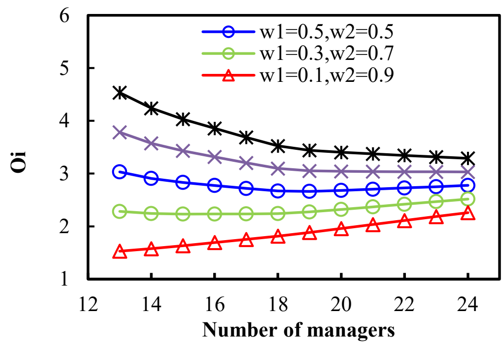


Figure 6: Objective function distribution under different weight assignments.

4 CONCLUSIONS

An optimization method for project managers based on particle swarm optimization is proposed in this paper. The manager optimization model, the project exception handling time model and the cost model are established respectively. The positions and numbers of managers are optimized to ensure timely handling of project exceptions while reducing management costs. The project with 4 tasks is studied as the research object, and the research results show that the managers optimization model based on particle swarm optimization has efficient convergence. Experiments show that for a project with the number of sub-tasks is 10, 8, 8, 6, and 4, when the number of managers is greater than 19, the effect of increasing the number of managers is no longer significant. When the optimization goal is set to be no higher than 4000 total management costs, the project requires 17 managers. The objective function equation is introduced to discuss 192 combination schemes. Through the proper selection of dimensionless parameters and weighting factors, the optimal solution of the model can be quantitatively evaluated and obtained. The distribution of weighting factors can realize the multi-objective and unbalanced guiding needs of decision makers.

Based on the method proposed in this paper, several challenges and direction can be further studied. First, a quantitative algorithm for the ability of managers is important, because the managers are arranged more reasonably with this quantitative algorithm. What's more, the ability to deal with emergencies of a management team also needs to be evaluated.

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