



Article Research on the Mathematical Model for Optimal Allocation of Human Resources in the Operation and Maintenance Units of a Heavy Haul Railway

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Abstract: According to the existing personnel structure, quantity, development strategy, and market demand of the Shuohuang Railway Company's operation and maintenance project, the demand quantity of various employees of the company for the past three years is predicted, and a human resource optimization model based on existing human resources and future plans is established. Then, the optimal solutions of the two mathematical models were calculated and analyzed using LINGO software. Finally, combined with the actual situation, the optimal allocation of human resources for the operation and maintenance project of KY company was obtained. The following conclusions are obtained. (1) For the optimal allocation model of existing human resources, the maximum net profit of the optimal staffing model is CNY 3258000. (2) The human resources allocation cost of the lowest cost model is CNY 15500. The research results can effectively guide the human resource management of the operation and maintenance project of the Shuohuang Railway Company, and have important theoretical and practical significance for further analysis of human resources model and its optimal allocation method.

Keywords: heavy haul railway; human resources; mathematical model; optimal allocation

MSC: 00A71

1. Introduction

Human resource management is critical in project management and has an important impact on the competitiveness and overall development of enterprises. The value of human resources is significantly reflected in the process of allocating human resources [1–5].

In the development and competition of enterprises, human resource management has a great impact. Moreover, the level of human resource management ability is also directly related to the economic benefits of enterprises and projects. In order to generate increased profits for enterprises and projects, human resources should apply adjustments in the recruitment system, dismissal system, training system, and evaluations [6–15]. Human resource allocation is the management and control of enterprise human resources based on project organization, with the aim of improving efficiency and maximizing the value of human resource management. Human resource allocation should therefore aim at enhancing the effect of human resource management and ensuring a match between personnel ability and position.

The concept of human resource management is derived from traditional personnel management. The Industrial Revolution gave birth to personnel management activities. After 1970, countries all over the world began to change their management ideas. The



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Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https:// creativecommons.org/licenses/by/ 4.0/). concept of personnel management was gradually eliminated, and the concept of human resource management was gradually formed. In combing through the research conclusions of studies, it is found such research has experienced the following stages of development [15–20].

Bakke E. W. published the book *Human Resources Function* in 1958, which elaborated on issues related to the management of human resources. He discussed the management of human resources as a general function of management [21].

Ferguson (1960) [22] summarized the development of human resource management in the United States. Farmer (1958) [23] traced the practice of human resource management in Britain. In 1953, Hanel analyzed the impact of the political atmosphere of a country where an enterprise is located on the theory and practice of human resource management [24].

Cicourel (1958) believes that both formal and informal organizational factors within an organization have an important impact on human resource management [25].

In the mid-1970s, many scholars equated human resource management with personnel management. As Robbins described in his book *Personnel, the management of Human Resources*, today, personnel management aims to study the organization's human resources and how to make them serve the organization's goals more effectively [26]. Henneman, Schwab, Fossum, and Dyer used the term "Personnel/Human resource management" in their papers and equated human resource management with personnel management [27].

In the 1980s, the research on human resources and its management achieved fruitful results.

The most influential and strategic human resource management theory was put forward by Beer and others in their book *Managing Human Capital* in 1984. Beer and others believed that human resource management policies should be selected according to four aspects: (1) employee influence; (2) human resource flows, both within and outside the organization; (3) remuneration systems; and (4) working systems [28]. Fombrun (1984) [29] paid great attention to the importance of strategic means. That is to say, the company's strategy and human resource management's strategy are related in many aspects, such as structure, culture, and employees resources and development.

Around the definition of the concept, essence, scope, and objectives of human resource management, Walton (1985) [30] proposed a human resource management policy: clarifying common objectives, mutual influence, mutual respect, mutual reward, and mutual responsibility. Storey (1992) [31] analyzed the internal characteristics of human resource management and believed that there are 27 differences between personnel management and human resource management. He divided the 27 differences into three categories: beliefs and assumptions; strategic areas; and importance. Kamoche (1996) [32] studied the human resource management capability of enterprises, while Schuler and Huber (1993) [33] studied the purpose, behavior, and role of human resource management.

With the deepening of human resource management research, Legee (1989) [34] linked culture with human resource management; Legee believes that the real focus of human resource management is organizational culture as well as its change and management. Culture is closely connected with organizational strategy and structure and also has an impact on employee recruitment, selection, evaluation, training, and reward. Moorhead and Griffin (1992) [35] believe that organizational culture is a set of values that helps people in organizations understand which behaviors are acceptable and which are unacceptable. These values often circulate among employees in stories or other symbolic ways. Ouchi (1981) [36] attributed Japan's economic success in the early 1980s to the combination of the American and Japanese models in his Z theory, specifically the emphasis on people, long-term employment guarantee, being based on value sharing and collective decisionmaking, the participation of "small groups" and the social pressure on performance, high trust in the final judgment of managers, and the nonspecialized career promotion path. The final result is mutual obligation; that is, employees respond to the employer's commitments to them with a sense of responsibility to the organization. Peters and Waterman (1982) [37] focused on the relationship between American organizational culture and performance

when analyzing various successful management models. Cheng (2020, 2021) [38–42] analyzed the factors influencing land-leasing based on mathematical models.

The quantitative analysis and optimal allocation model of human resources has been recognized by increasing numbers of researchers and project managers. At the macro level, the value of human resources has begun to be reflected in the national strategic level, and China has successively implemented numerous human resources development policies. At the micro level, human resource planning, development, training, and management have become the basic content of project organization and management, and the effect of human resource management is more ideal.

It is of great significance to carry out a quantitative analysis of human resources and research into human resource optimization allocation to improve the enterprise efficiency and competitiveness of the Shuohuang Railway Company's operation and maintenance project in the past three years based on the following rationales:

- (1) Helping the project improve the effect of human resource management and improving the comprehensive competitiveness of the enterprise. The current project is facing fierce competition and a more complex competition pattern. It is impossible for enterprises to realize long-term competitive advantage based on one kind of competitiveness. Following its emergence, the project's competitive advantage will be constantly imitated and then gradually disappear. Competitive advantage formed on the basis of core human resources, however, is unique and therefore difficult for other enterprises to copy and surpass. Therefore, the project needs to establish the mechanisms for the right human resources management;
- (2) Achieving the profit maximization effect, based on cost minimization. First, in the process of staff allocation, we should consider the ability and experience of employees to ensure that the results after distribution can support the realization of the personal value of employees. Under the control of human resources, employees can communicate in a timely manner and flexibly adjust their work, thus effectively reducing the operating cost;
- (3) Improving the skills and quality of employees to promote the technological renewal of enterprises. Circulation of information together with improving the technical ability of employees can be realized through the exchange of information between employees in the project. This is very beneficial for the mining of staff skills and abilities, which can help the enterprise to continuously develop.

The method based on mathematical models can characterize the quantitative distribution of all kinds of human resources and thus fulfill the objective and serve as an effective decision-making basis for enterprise managers.

The main goal of this paper is to create the maximum net profit according to the existing human resources. Then, according to the human resource planning in the next three years, the optimal allocation scheme of the minimum dismissal model and the minimum cost model is obtained.

Therefore, this paper analyzes the optimal allocation of human resources under the existing human resources conditions by establishing an optimal allocation model based on the existing human resources and the dynamic optimization model based on the future plans of human resources. Furthermore, the optimal allocation of human resources is considered under conditions of either minimum dismissal (when the Shuohuang Railway Company's operation and maintenance project benefit is high) or lowest cost (when the Shuohuang Railway Company's operation and maintenance project benefit is low) and can effectively improve the utilization efficiency, transportation efficiency, and profit rate through the Shuohuang Railway Company's human resources.

Because there are many uncertainties in the future transportation conditions, the possible changes of transportation elasticity [43,44] and external costs [45,46] are not considered in this paper.

The main methods adopted in this paper are:

(1) Literature induction

Collect, analyze, and study relevant literature on the optimal allocation of human resources at home and abroad; carefully sort out, analyze, summarize, and select the theory and method of optimal allocation of human resources related to the paper to achieve the purpose of investigation and research;

(2) Questionnaire survey method

Through the questionnaire survey method, collect and sort out the planning data of the transportation project of the Shuohuang Railway Company in terms of post establishment, recruitment, dismissal, training, etc., as the material of this quantitative study;

(3) Mathematical modeling method

According to the existing human resources and future plans of the transportation project of the Shuohuang Railway Company, a mathematical model for the optimal allocation of existing human resources in the four bridge and tunnel operation and maintenance units of the transportation project of the Shuohuang Railway Company, as well as the minimum dismissal and costs in the next three years, is established. Then, Lingo software is used to analyze and calculate the optimal solution of the two mathematical models, and the optimal allocation of human resources in the transportation project of the Shuohuang Railway Company is obtained based on the actual situation.

2. Current Human Resource Allocation Overview

This section takes the four bridge and tunnel operation and maintenance units of the Shuohuang Railway Company as an example to optimize human resource allocation. There are 328 managers, senior workers, intermediate workers, and junior workers. According to the quantitative analysis in the above sections, the average salary level distribution of all types of personnel is shown in Table 1.

Table 1. Distribution of human resources category and wage level of bridge and tunnel operation and maintenance unit of the Shuohuang Railway Company's operation and maintenance project.

Personnel Category	Management	Senior Worker	Intermediate Worker	Junior Worker
Number of people	16	64	156	92
Salary (CNY/month)	8000	6000	5000	4000

The four bridge and tunnel operation and maintenance units A, B, C and D of the Shuohuang Railway Company are located in Yuanping, Dongye, Xiaojue, and Suning, respectively. Due to the different economic conditions and freight volume in the four regions, the contribution of different types of personnel to the average transportation benefits of each bridge and tunnel operation and maintenance unit differs, as shown in Table 2.

Table 2. Average transportation benefits of all types of personnel.

Powennal Catagowy	Average Transportation Benefit (CNY/Month)				
reisonner Category	A	В	С	D	
Management	30,000	20,000	26,000	15,000	
Senior worker	22,000	10,000	16,000	8000	
Intermediate Worker	18,000	15,000	13,000	12,000	
Junior worker	15,000	8000	10,000	6000	

3. Analysis of the Optimal Allocation Model Based on Existing Human Resources *3.1. Model Hypothesis*

- (1) All types of personnel are paid a fixed salary every month;
- (2) The four bridge and tunnel operation and maintenance units are working every day, and there is no suspension of the bridge and tunnel operation and maintenance units;

- (3) No additional temporary recruiters;
- (4) The same person is not considered as two bridge and tunnel operation and maintenance units at the same time;
- (5) The influence of various factors on the bridge and tunnel operation and maintenance unit and staff is excluded;
- (6) This paper does not consider many of the uncertainties of future transportation conditions, including possible changes in transportation elasticity and external costs.

3.2. Model Construction

(1) Definitions

A, *B*, *C*, *D*: the operation and maintenance unit of each bridge and tunnel;

 x_{ij} : the number of the *i*-th type personnel required for the *j*-th bridge and tunnel operation and maintenance unit;

c_{ij}: the average transportation benefit of the *i*-th type personnel assigned to the *j*-th bridge and tunnel operation and maintenance unit;

R: the direct income of four bridge and tunnel operation and maintenance units;

Q: the total wages paid to 328 personnel per month;

W: the direct transportation benefits, W = R - Q;

 W_1 : the direct income of the fixed part;

 W_2 : the direct income from the assignment;

 ρ_{ij} : the net profit generated by the *i*-th type personnel as the *j*-*j*-th bridge and tunnel operation and maintenance unit to the company;

*k*_{*i*}: the salary paid by the four bridge and tunnel operation and maintenance units to the *i*-th type personnel.

(2) Model preparation

First, we make a rough estimate of the model.

Suppose ρ_{ij} represents the net profit brought to the company when the *i*-th type person assigned to the *j*-th bridge and tunnel operation and maintenance unit. k_i represents the monthly salary the company gives to its personnel. c_{ij} represents the average transportation benefit created by the *i*-th type personnel as the *j*-th bridge and tunnel operation and maintenance unit. Then:

$$\rho_{ii} = c_{ii} - k_i (j = 1, 2, 3, 4).$$

From this, we come to the values of ρ_{ij} shown in Table 3.

Table 3. The net profit statement of each unit and personnel structure.

$ ho_{11}$	$ ho_{12}$	$ ho_{13}$	$ ho_{14}$	$ ho_{21}$	$ ho_{22}$	ρ ₂₃	$ ho_{24}$
22,000	12,000	18,000	7000	16,000	4000	10,000	2000
$ ho_{31}$	<i>ρ</i> ₃₂	$ ho_{33}$	$ ho_{34}$	$ ho_{41}$	$ ho_{42}$	$ ho_{43}$	$ ho_{44}$
13,000	10,000	8000	7000	11,000	4000	6000	2000

(3) Integer programming model

Through careful analysis of the problem, it can be described through the integer programming model: i = 1, 2, 3, 4 refers to the personnel type, namely 1—management personnel, 2—senior worker, 3—intermediate worker, 4—junior worker; j = 1, 2, 3, 4 is the type of bridge and tunnel operation and maintenance unit, where 1—bridge and tunnel operation and maintenance unit A, 2—bridge and tunnel operation and maintenance unit B, 3—bridge and tunnel operation and maintenance unit C, 4—bridge and tunnel operation and maintenance unit D; $x_{ij}(i = 1, 2, 3, 4; j = 1, 2, 3, 4)$ represents the number of *i*-th class personnel required by the *j*-th bridge and tunnel operation and maintenance unit; c_{ij} represents the benefit standard of *i*-th class personnel required by the *j*-th bridge and tunnel

operation and maintenance unit; Q is the total monthly wage; R is the total monthly income of the four bridge and tunnel operation and maintenance units. The net profit created by the company is W = R - Q. The total salary is $Q = 8000 \times 16 + 6000 \times 64 + 5000 \times 156 + 4000 \times 92 = \text{CNY}$ 1660000.

The integer programming model with maximum benefit can be established as follows:(4) Objective function

Max
$$W = \sum_{i=0}^{4} \sum_{j=0}^{4} c_{ij} x_{ij} - 1660000 = \sum_{i=0}^{4} \sum_{j=0}^{4} \rho_{ij} x_{ij}$$

(5) Constraints

According to the overall transportation benefits of each bridge and tunnel operation and maintenance unit of the Shuohuang Railway Company's operation and maintenance project, the structural restrictions of various personnel in each bridge and tunnel operation and maintenance unit can be estimated, as shown in Table 4.

Table 4. Personnel structure restrictions of each bridge and tunnel operation and maintenance unit.

Parsonnal Catagory	Personnel Structure Restrictions				
reisonner Category	Α	В	С	D	
Management	8~10 8~10	2~4 2~4	4~8 4~8	2~4 2~4	
Senior worker	20~30 20~30	$\geq \!$	16~24 16~24	$\geq 10 \\ \geq 10$	
Intermediate worker	≥ 50 ≥ 50	30~36 30~36	$\geq 40 \\ \geq 40$	20~30 20~30	
Junior worker	\geq 30 \geq 30	≥ 16 ≥ 16	$\geq \!\geq \!\!\!\!\!\!\!\!\!\!$	$\geq 12 \\ \geq 12$	
Total	$\leq 130 \leq 130$	≤90 ≤90	$\stackrel{\leq 110}{\leq 110}$	$\leq 70 \leq 70$	

3.3. Model Solving

LINGO 11 software (developed by Lindo System Inc. located in Chicago, IL, USA) is used to write and solve the program for the human resources optimal allocation model. The results of the program operation are shown in Figure 1.

Solution Report - LINGO1			×
Global optimal solution found.			^
Objective value:	325	8000.	
Infeasibilities:	0.0	00000	
Total solver iterations:		5	
Variable X11 X21 X31 X41 X12 X22 X32 X42 X13	Value 8.000000 24.00000 32.00000 2.000000 14.00000 30.00000 16.00000 4.000000	Reduced Cost 0.000000 0.000000 0.000000 0.000000 0.000000	
X23	16.00000	0.000000	
X33	40.00000	0.000000	
X43	32.00000	0.000000	
X14	2.000000	0.000000	
X24	10.00000	0.000000	
X34	20.00000	0.000000	
X44	12.00000	0.000000	
У	1.000000	0.000000	
			~

Figure 1. Operation results.

The optimal personnel structure allocation model of four bridge and tunnel operation and maintenance units of the Shuohuang Railway Company's operation and maintenance project is solved by LINGO software, as shown in Table 5. The maximum net profit of the optimal personnel structure allocation model is CNY 3258000.

Parconnal Catagory	Optimal Staffing Structure			
reisonner Category	Α	В	С	D
Management	8	2	4	2
Senior worker	24	14	16	10
Intermediate worker	66	30	40	20
Junior worker	32	16	32	12
Total	130	62	92	44

Table 5. Optimal staffing structure.

The variables according to their sensitivity from large to small are as follows:

 $x_{11} \ge x_{13} \ge x_{21} \ge x_{31} \ge x_{12} \ge x_{23} \ge x_{33} \ge x_{41} \ge x_{12} \ge x_{43} \ge x_{14} = x_{34} \ge x_{22} = x_{42} \ge x_{24} \ge x_{44}$

Through the sensitivity test of the model shown in Table 5, it is found that the optimal allocation model of human resources is reasonable, the benefits to transportation are the largest, and the restrictions of personnel structure are fully met.

4. Analysis of the Optimal Allocation Model of Human Resources in the Past Three Years

4.1. Human Resources Planning

According to the existing personnel structure, quantity, development strategy, and market demand for the operation and maintenance project of the Shuohuang Railway Company, the demand quantity of various employees of the company in the past three years can be predicted, as shown in Table 6. As the number of senior workers in the operation and maintenance project of the Shuohuang Railway Company is small and remains unchanged, it is only necessary to make adjustments to the intermediate workers and junior workers of the Shuohuang Railway Company through recruitment, retraining, demotion, dismissal, additional recruitment, and recruitment of non-staff personnel, so as to establish the optimal dynamic adjustment scheme of the personnel structure to meet the requirements of the Shuohuang Railway Company.

Table 6. Demand quantity of bridge and tunnel operation and maintenance units of operation and maintenance project of the Shuohuang Railway Company.

Personnel Category	Management	Aanagement Senior Worker		Junior Worker
Current number	16	64	156	92
First year	16	80	128	86
Second year	16	94	102	76
Third year	16	106	76	28

Due to the automatic dismissal of workers or for other reasons, the operation and maintenance project of the Shuohuang Railway Company has the problem of natural attrition. Table 7 shows the natural dismissal rate of the bridge and tunnel operation and maintenance unit of the operation and maintenance project of the Shuohuang Railway Company.

Classification	Junior Worker	Intermediate Worker	Senior Worker
Less than one year	20%	15%	9%
of work	20%	15%	9%
Work for more than one year of work	10%	6%	3%
	10%	6%	3%

Table 7. Division of natural dismissal rate of bridge and tunnel operation and maintenance unit of operation and maintenance project of the Shuohuang Railway Company.

As the recruitment cycle is one year, the existing workers have worked for more than one year.

(1) Recruitment

There are no more than two senior workers, three intermediate workers, and eight junior workers who can recruit new workers every year;

(2) Training

The cost of training intermediate workers to become senior workers is CNY 1000/person/year, and the number of trainees cannot exceed $\frac{1}{4}$ of the number of senior workers in the training position at that time. The cost of training junior workers to become intermediate workers is CNY 800/person/year (five persons/year);

(3) Lower level

Incompetent workers can be demoted. Although the company does not need to pay fees, 40% of the workers who are demoted will be dismissed;

(4) Dismissal

The dismissal cost of senior workers is CNY 1000/person, the dismissal cost of intermediate workers is CNY 800/person, and the dismissal cost of junior workers is CNY 500/person;

(5) Overemployment

Each type of personnel of the whole company can employ five more than needed to cope with the rapid development environment of the logistics market. The additional cost is CNY 3000/person/month for junior workers, CNY 4000/person/month for intermediate workers, and CNY 6000/person/month for senior workers;

(6) Non-staff personnel

Junior workers, intermediate workers, and senior workers can each have no more than 50 non-staff personnel to complete the production task of half a person. In this way, the company pays CNY 3000/person/month.

4.2. Human Resource Model Analysis

(1) Minimum dismissal model

When the Shuohuang Railway Company has high transportation efficiency, the dismissal of employees needs to be subsidized to pay to ensure company humanization. If too many employees are dismissed, this may impact on the company's economy. The first model is unilaterally considered from the number of personnel along with a variety of factors, and the company also adopts methods for training, recruitment, demotion, and non-staff personnel. In the establishment of the mathematical model, all of the factors involved are taken into account as limiting conditions in the optimization data. Demotion will result in the dismissal of 40% of workers, excluding natural dismissal. In summary, the company's requirements for the number of people are gradually increasing, the demand for senior workers and intermediate workers is gradually decreasing, and the demand for junior workers is gradually increasing. When the transportation efficiency of the Shuohuang Railway Company is poor, personnel changes are bound to occur due to economic factors. Whether it is through dismissal or non-staff personnel and training, economic expenditure will be incurred. Obviously, under a reasonable scope and arrangement, the establishment of the mathematical model and linear optimization can find the best scheme.

4.3. Model Hypothesis

- Assuming that the number of workers per year is just the estimated number, recruitment will occur in strict accordance with demand. The maximum number of recruits is the sum of the estimated workforce demand of the current year and the number of overstaffed workers;
- (2) Assuming that the cost is considered, only recruitment, training, demotion, and dismissal are involved. The salary and workload of all types of work are not taken into account;
- (3) Demotion does not only consider demotion; that is, senior workers are demoted to intermediate workers, intermediate workers are demoted to junior workers, and senior workers can also be demoted to junior workers;
- (4) The processes of staff reduction, recruitment, dismissal, retraining, and establishment of non-staff personnel are carried out in a short time at the beginning of each year, and recruitment, demotion, dismissal, and retraining are carried out after natural staff reduction;
- (5) After adjustment at the beginning of each year, the workforce demand of the Shuohuang Railway Company's operation and maintenance project can be met, and there will be no changes to personnel in the next year;
- (6) When calculating the workload, a non-staff member is equal to half a regular worker. When calculating recruitment, retraining, demotion, dismissal, and overemployment dismissal, a non-staff person is calculated as an independent person. Non-staff personnel are the result of the company's transfer of various types of work according to the needs of personnel transfer;
- (7) All types of workers (senior workers, intermediate workers, and junior workers) have the same opportunities to be dismissed, demoted, promoted, and trained;
- (8) This paper does not consider many of the uncertainties of future transportation conditions, including possible changes in transportation elasticity and external costs.
- 4.4. Model Building
- (1) Definition

 X_{ij} : *j*-th type workers employed in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, and 3 represents senior workers).

 XC_{ij} : *j*-th type workers dismissed in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, and 3 represents senior workers).

 XD_{ij} : recruitment of *j*-th type workers among non-staff personnel in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, 3 represents senior workers).

 XE_{ij} : additional *j*-th type workers recruited in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, 3 represents senior workers).

 XZ_{ij} : *j*-th type workers recruited in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, 3 represents senior workers).

XP_{ij}: *j*-th type workers trained in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, 3 represents senior workers).

 XJ_{ij} : *j*-th type workers demoted in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents junior workers, 2 represents intermediate workers, 3 represents senior workers).

 XH_{ij} : *j*-th type workers promoted after demotion in the *i*-th year (*i* represents the number of years from 0 to 3; *j* indicates the type of worker, where 1 represents intermediate workers recovered after demotion, 2 represents senior workers that were promoted to intermediate level after being demoted, 3 represents senior workers recovered after being demoted to intermediate level, and 4 represents senior workers recovered after being demoted to primary level). Workers who have been reinstated do not need additional training.

- (2) Decision of variables:
- (1) Set the data in Table 3 as X_{ij} :

$$X_{01} = 92; X_{02} = 156; X_{03} = 64; X_{11} = 86; X_{12} = 128; X_{13} = 80$$

 $X_{21} = 76; X_{22} = 102; X_{23} = 94; X_{31} = 28; X_{32} = 76; X_{33} = 106;$

② Number of workers recruited:

In the first year, the number of junior workers recruited is XZ_{11} , the number of intermediate workers recruited is XZ_{12} , the number of senior workers recruited is XZ_{13} .

In the second year, the number of junior workers recruited is XZ_{11} , the number of intermediate workers recruited is XZ_{12} , the number of senior workers recruited is XZ_{13} .

In the third year, the number of junior workers recruited is XZ_{11} , the number of intermediate workers recruited is XZ_{12} , the number of senior workers recruited is XZ_{13} .

It is known that $XZ_{i1} \le 10$, $XZ_{i2} \le 20$, $XZ_{i3} \le 6$ (*i* = 1, 2,3).

③ Number of workers trained:

In the first year, the number of junior workers trained is XP_{11} , the number of intermediate workers trained is XP_{12} .

In the second year, the number of junior workers trained is XP_{21} , the number of intermediate workers trained is XP_{22} .

In the third year, the number of junior workers trained is XP_{31} , the number of intermediate workers trained is XP_{32} .

$$XP_{i1} \leq 30, XP_{i2} \leq 1/4 X_{i1}.$$

$$XP_{i1} \leq 30, XP_{i2} \leq 1/4.$$

The training cost is $P = \sum (800 \times XP_{i1} + 1000 \times XP_{i2})$ (*i* = 1,2,3).

④ Number of workers demoted:

 $X J_{ij}$ (*i* represents the number of years from 0 to 3; *j* indicates the type of worker represented, where 1 represents intermediate workers demoted to junior workers, 2 represents senior workers demoted to junior workers, 3 represents senior workers demoted to intermediate workers).

$$\begin{aligned} XJ_{ij} &\leq X_{i2} \times (1-6\%) + XZ_{i2} \times (1-15\%) \\ XJ_{i2} + XJ_{i3} &\leq X_{i3} \times (1-3\%) + XZ_{i3} \times (1-9\%), \ (i = 1, 2, 3). \end{aligned}$$

(5) The number of demoted workers who are promoted again:

$$\begin{split} XH_{1j} &= 0 \\ XH_{21} - XJ_{11} \times (1 - 40\%) \times (1 - 10\%) \leq 0. \\ XH_{22} + XH_{24} - XJ_{12} \times (1 - 40\%) \times (1 - 10\%) \leq 0. \\ XH_{23} - XJ_{13} \times (1 - 40\%) \times (1 - 6\%) \leq 0. \\ XH_{31} - (XJ_{21} \times (1 - 40\%) + XJ_{11} \times (1 - 40\%) \times (1 - 10\%) - XH_{21}) \times (1 - 10\%) \leq 0. \\ XH_{32} + XH_{34} - (XJ_{22} \times (1 - 40\%) + XJ_{12} \times (1 - 40\%) \times (1 - 10\%) - XH_{24}) \times (1 - 10\%) \leq 0 \\ XH_{33} - (XJ_{23} \times (1 - 40\%) + XJ_{13} \times (1 - 40\%) \times (1 - 6\% - XH_{23} + XH_{22}) \times (1 - 6\%) \leq 0. \end{split}$$

Note: promotion is only for workers who were demoted in the previous year.

6 Number of workers dismissed:

$$\begin{split} &XC_{11} - X_{01} \times (1 - 10\%) + XP_{11} \leq 0, \ XC_{12} - X_{02} \times (1 - 6\%) + XP_{12} \leq 0. \\ &XC_{13} - X_{03} \times (1 - 3\%) + XP_{13} \leq 0, \ XC_{21} - X_{11} \times (1 - 10\%) + XP_{21} \leq 0. \\ &XC_{22} - X_{12} \times (1 - 6\%) + XP_{22} \leq 0, \ XC_{23} - X_{13} \times (1 - 3\%) + XP_{23} \leq 0. \\ &XC_{31} - X_{21} \times (1 - 10\%) + XP_{31} \leq 0, \ XC_{32} - X_{22} \times (1 - 6\%) + XP_{32} \leq 0. \\ &XC_{33} - X_{23} \times (1 - 3\%) + XP_{33} \leq 0. \end{split}$$

The dismissal fee is $C = \sum (500 \times C_{i1} + 800 \times C_{i2} + 1000 \times C_{i3})$, (i = 1,2,3).

⑦ Additional recruitment of all types of worker per year: $\sum XE_{ij} ≤ 4$.

The additional recruitment costs are $E = \sum (4000 \times XE_{i1} + 5000 \times XE_{i2} + 6000 \times XE_{i3}).$

(8) Number of non-staff recruited every year: $XD_{ij} \leq 20$.

The expenses for recruiting non-staff are $D = \sum (3000 \times XD_i)$.

(3) Establish objective function:

The decision variables are integrated, and the minimum dismissal model and cost minimum model are established for further analysis.

1.	Objective function of minimum	m dismissal: <i>N</i>	$\Lambda IN \sum_{i}^{3} \sum_{j=1}^{3} c_{j}$	ij

	$0 \leq XZ_{i1} \leq 10;$	(i = 1, 2, 3)	
	$0 \leq XZ_{i2} \leq 20;$	(i = 1, 2, 3)	
	$0 \leq XZ_{i3} \leq 6;$	(i = 1, 2, 3)	
	$0 \leq XP_{i1} \leq 30;$	(i = 1, 2, 3)	
	$0 \le XP_{i2} \le 1/4 \times X_{i1};$	(i = 1, 2, 3)	
	$0 \le XJ_{i1} \le X_{i2} \times (1 - 6\%) + XZ_{i2} \times (1 - 15\%);$	(i = 1, 2, 3)	
	$0 \le XJ_{i2} + XJ_{i3} \le X_{i3} \times (1 - 3\%) + XZ_{i3} \times (1 - 9\%);$	(i = 1, 2, 3)	
	$XH_{1i}=0;$	(i = 1, 2, 3, 4)	
	$XH_{21} - XJ_{11} \times (1 - 40\%) \times (1 - 10\%) \le 0;$		
	$XH_{22} + XH_{24} - XJ_{12} \times (1 - 40\%) \times (1 - 10\%) \le 0;$		
	$XH_{23} - XJ_{13} \times (1 - 40\%) \times (1 - 6\%) \le 0;$		
	$ \left XH_{31} - \left[\begin{array}{c} XJ_{21} \times (1 - 40\%) + XJ_{11} \times (1 - 40\%) \\ \times (1 - 10\%) - XH_{22} \end{array} \right] \times (1 - 10\%) \le 0; $		
s.t.	$\begin{vmatrix} XH_{32} + XH_{34} - \begin{bmatrix} XJ_{22} \times (1 - 40\%) + XJ_{12} \times \\ (1 - 40\%) \times (1 - 10\%) + XH_{24} \end{vmatrix} \times (1 - 10\%) \le 0;$		(1)
	$XH_{33} - \begin{bmatrix} XJ_{23} \times (1 - 40\%) + XJ_{13} \times (1 - 40\%) \\ \times (1 - 6\%) - XH_{23} + XH_{22} \end{bmatrix} \times (1 - 6\%) \le 0;$		
	$XC_{i1} - X_{j1} \times (1 - 10\%) - XP_{i1} \le 0;$	(i = 1, 2, 3; j = 0, 1, 2)	
	$XC_{i2} - X_{j2} imes (1 - 6\%) - XP_{i2} \le 0;$	(i = 1, 2, 3; j = 0, 1, 2)	
	$XC_{i3} - X_{j3} \times (1 - 10\%) - XP_{i3} \le 0;$	(i = 1, 2, 3; j = 0, 1, 2)	
	$0 \leq \sum_{i=1}^{3} \sum_{j=1}^{3} XE_{ij} \leq 4;$	(i = 1, 2, 3; j = 1, 2, 3)	
	$X_{i1} \times (1 - 10\%) + XZ_{j1} \times (1 - 20\%) + (XJ_{j1} + XJ_{j2}) \times (1 - 40\%)$		
	$- XP_{j1} - XC_{j1} - XE_{j1} = X_{j1};$	(i = 0, 1, 2; j = 1, 2, 3)	
	$X_{i2} \times (1-6\%) + XZ_{j1} \times (1-15\%) + XJ_{j3} \times (1-40\%) - XJ_{j1}$		
	$+ XP_{j1} - XP_{j2} - XC_{j1} - XE_{j1} = X_{j2};$	(i = 0, 1, 2; j = 1, 2, 3)	
	$X_{i3} \times (1 - 3\%) + XZ_{j1} \times (1 - 9\%) - XJ_{j2} - XJ_{j3} + XP_{j2}$		
	$- XC_{j3} - XE_{j3} + XH_{j3} + XH_{j4} = X_{j3}.$	(i = 0, 1, 2; j = 1, 2, 3)	

2.

Objective function of minimum cost model: $MIN \sum_{i}^{3} \sum_{j=1}^{3} (P_{ij} + $	$C_{ij}+E_{ij}+D_{ij}\big)$	
$ \begin{array}{l} 0 \leq XZ_{i1} \leq 10; \\ 0 \leq XZ_{i2} \leq 20; \\ 0 \leq XZ_{i3} \leq 6; \\ 0 \leq XP_{i1} \leq 30; \\ 0 \leq XP_{i2} \leq 1/4 \times X_{i1}; \\ 0 \leq XJ_{i1} \leq X_{i2} \times (1 - 6\%) + XZ_{i2} \times (1 - 15\%); \\ 0 \leq XJ_{i2} + XJ_{i3} \leq X_{i3} \times (1 - 3\%) + XZ_{i3} \times (1 - 9\%); \\ XH_{1i} = 0; \\ XH_{21} - XJ_{11} \times (1 - 40\%) \times (1 - 10\%) \leq 0; \\ XH_{22} + XH_{24} - XJ_{12} \times (1 - 6\%) + XJ_{11} \times (1 - 40\%) \\ XH_{23} - XJ_{13} \times (1 - 40\%) \times (1 - 6\%) \leq 0; \\ XH_{31} - \begin{bmatrix} XJ_{21} \times (1 - 40\%) + XJ_{11} \times (1 - 40\%) \\ \times (1 - 10\%) - XH_{22} \end{bmatrix} \times (1 - 10\%) \leq 0; \\ \end{array} $	(i = 1, 2, 3) $(i = 1, 2, 3)$ $(i = 1, 2, 3, 4)$	
s.t. $\begin{cases} XH_{32} + XH_{34} - \begin{bmatrix} XJ_{22} \times (1 - 40\%) + XJ_{12} \times \\ (1 - 40\%) \times (1 - 10\%) + XH_{24} \end{bmatrix} \times (1 - 10\%) \le 0; \\ XH_{33} - \begin{bmatrix} XJ_{23} \times (1 - 40\%) + XJ_{13} \times (1 - 40\%) \\ \times (1 - 6\%) - XH_{23} + XH_{22} \end{bmatrix} \end{bmatrix} \times (1 - 6\%) \le 0; \\ XC_{i1} - X_{j1} \times (1 - 10\%) - XP_{i1} \le 0; \\ XC_{i2} - X_{j2} \times (1 - 6\%) - XP_{i2} \le 0; \\ XC_{i3} - X_{j3} \times (1 - 10\%) - XP_{i3} \le 0; \end{cases}$	(i = 1, 2, 3; j = 0, 1, 2) (i = 1, 2, 3; j = 0, 1, 2) (i = 1, 2, 3; j = 0, 1, 2)	(2)
$\begin{split} 0 &\leq \sum_{i=1}^{3} \sum_{j=1}^{3} XD_{ij} \leq 20; \\ 0 &\leq \sum_{i=1}^{3} \sum_{j=1}^{3} XE_{ij} \leq 4; \\ X_{i1} &\times (1 - 10\%) + XZ_{j1} \times (1 - 20\%) + (XJ_{j1} + XJ_{j2}) \times (1 - 40\%) \\ &- XP_{j1} - XC_{j1} - XE_{j1} = X_{j1}; \\ X_{i2} &\times (1 - 6\%) + XZ_{j1} \times (1 - 15\%) + XJ_{j3} \times (1 - 40\%) - XJ_{j1} \\ &+ XP_{j1} - XP_{j2} - XC_{j1} - XE_{j1} = X_{j2}; \\ X_{i3} &\times (1 - 3\%) + XZ_{j1} \times (1 - 9\%) - XJ_{j2} - XJ_{j3} + XP_{j2} \end{split}$	(i = 1, 2, 3; j = 1, 2, 3) (i = 1, 2, 3; j = 1, 2, 3) (i = 0, 1, 2; j = 1, 2, 3) (i = 0, 1, 2; j = 1, 2, 3)	
$- XC_{j3} - XE_{j3} + XH_{j3} + XH_{j4} = X_{j3}.$	(i = 0, 1, 2; j = 1, 2, 3)	

4.5. Model Solving

The program of the human resource optimization configuration model is compiled and solved using LINGO software.

(1) Minimum dismissal model

The number of dismissals, recruitments, trainings, demotions, and promotions of all types of personnel in the past three years is calculated according to rounding out and rounding, as shown in Tables 8–10. The minimum number of dismissed personnel is 0, and the cost of human resource allocation is CNY 81000.

Personnel Category		Junior Worker	Intermediate Worker	Senior Worker
	Current	92	156	64
Number of workers	First year	86	128	80
	Second year	76	102	94
	Third year	28	76	106
Number of dismissed	First year	0	0	0
workers YC.	Second year	0	0	0
workers AC_{ij}	Third year	0	0	0
Number of workers	First year	10	0	0
Number of Workers	Second year	7	0	0
recruited XZ_{ij}	Third year	6	0	0
Number of trained	First year	30	12	0
workers YP.	Second year	0	18	0
workers AT ij	Third year	0	7	0
Number of additional	First year	0	0	0
workers recruited YE	Second year	0	0	0
workers recruited AE_{ij}	Third year	0	4	0

Table 8. Optimization of flow of workers in the minimum dismissal model for the past three years.

Table 9. Number of demoted workers in the past three years.

Personnel Category		Intermediate to Senior	Junior to Senior	Junior to Intermediate
Number of demoted	First year	42	0	35
workers XJ_{ij}	Second year	0	0	2
	Third year	0	20	0

Table 10. Number of workers promoted after demotion in the past three years.

Personnel Category		Intermediate Workers Recovered after Demotion	Senior Workers Promoted to Intermediate Level after Being Demoted to Junior Level	Senior Workers Recovered after Being Demoted to Intermediate Level	Senior Workers Recovered after Being Demoted to Primary Level
Increase in the	First year	0	0	0	0
number of workers	Second year	0	0	0	3
after demotion XH_{ij}	Third year	0	0	4	43

(2) Lowest cost model

The number of dismissals, recruitments, trainings, demotions, and promotions after demotion of various personnel in the past three years are rounded, as shown in Tables 11–13. The cost of human resources allocation is CNY 15500.

Personnel Category	Junior Worker	Intermediate Worker	Senior Worker	
	Current	46	78	32
	First year	43	64	40
Number of workers	Second year	38	51	47
	Third year	14	38	53
	First year	1	0	0
Number of dismissed workers XC_{ij}	Second year	0	0	0
	Third year	0	0	0
	First year	0	0	6
Number of workers recruited XZ_{ij}	Second year	0	0	4
	Third year	0	0	0
	First year	0	12	0
Number of trained workers XP_{ij}	Second year	0	3	0
	Third year	0	0	0
Number of additional workers	First year	0	0	0
recruited VE	Second year	0	0	0
recruited ΛL_{ij}	Third year	0	0	0

Table 11. Optimal allocation of worker mobility in the lowest cost model for the past three years.

Table 12. Number of demoted workers in the lowest cost model for the past three years.

Personnel Category		Intermediate to Senior	Junior to Senior	Junior to Intermediate
Number of demoted workers XJ _{ij}	First year	6	0	0
	Second year	18	0	0
	Third year	9	30	0

Table 13. Number of workers promoted after demotion in the lowest cost model for the past three years.

Personnel Category		Intermediate Workers Recovered after Demotion	Senior Workers Promoted to Intermediate Level after Being Demoted to Junior Level	Senior Workers Recovered after Being Demoted to Intermediate Level	Senior Workers Recovered after Being Demoted to Primary Level
Increase the number	First year	0	0	0	0
of workers after	Second year	0	0	0	12
demotion XH_{ij}	Third year	0	0	11	64

5. Conclusions and Discussion

5.1. Conclusions

In this study, the demand quantity of various employees of the company in the past three years is predicted according to the existing personnel structure, quantity, development strategy, and market demand of the Shuohuang Railway Company's operation and maintenance project, and a human resource optimization model based on existing human resources and future plans is established. The following conclusions are obtained:

(1) Optimal allocation model of existing human resources

The optimal personnel structure allocation model of bridge and tunnel operation and maintenance unit of the Shuohuang Railway Company's operation and maintenance project is solved using LINGO software, as shown in Table 14. The optimal allocation model of human resources is reasonable, the benefits to transportation are the largest, and the restrictions of personnel structure are fully met. The maximum net profit of the optimal staffing model is CNY 1506000.

Personnel Category —	Optimal Staffing Structure			
	Α	В	С	D
Management	8	2	4	2
Senior worker	24	14	16	10
Intermediate worker	66	30	40	20
Junior worker	32	16	32	12
Total	130	62	92	44

Table 14. Optimal staffing structure.

(2) Optimal allocation scheme of the minimum dismissal model

The human resources allocation cost of the minimum dismissal model is CNY 81000.

- (i) Dismissal scheme: There is no need to dismiss workers;
- (ii) Recruitment scheme: Recruit 10 junior workers in the first year. Recruit 7 junior workers in the second year. A total of 6 junior workers were recruited in the second year;
- (iii) Staff training program: Training 30 junior workers and 12 intermediate workers in the first year. Training 18 intermediate workers in the second year. In the third year, 30 junior workers and 7 intermediate workers were trained;
- (iv) Additional recruitment scheme: Only four additional intermediate workers meeting the post requirements need to be recruited in the third year;
- (v) Employee demotion scheme: In the first year, 42 intermediate workers were demoted to junior workers and 35 senior workers were demoted to intermediate workers. In the second year, senior workers were demoted to two intermediate workers. In the third year, senior workers were demoted to 20 junior workers;
- (vi) Scheme for promotion and employment of workers after demotion: three workers will be restored after senior workers are demoted to junior workers in the second year. In the third year, 4 senior workers were reinstated after being demoted to intermediate workers, and 43 senior workers were reinstated after being demoted to primary workers.
- (3) Optimal allocation scheme of the lowest cost model

The human resources allocation cost of the lowest cost model is CNY 15500.

- Dismissal plan: dismiss one junior worker whose working ability is not competent for the post requirements in the first year. There is no need to dismiss any category of worker in the second and third years;
- (ii) Recruitment Scheme: recruit six senior workers in the first year. Recruit four senior workers in the second year. In the third year, there is no need to recruit any type of worker;
- (iii) Staff training program: a total of 12 intermediate workers will be trained in the first year. Three intermediate workers will be trained in the second year. In the third year, there is no need to train any type of worker;
- (iv) Additional recruitment scheme: there is no need to recruit any additional category of worker;
- (v) Scheme for demotion of workers: in the first year, intermediate workers are demoted to six junior workers. In the second year, intermediate workers were demoted to 18 junior workers. In the third year, intermediate workers were demoted to 9 junior workers and senior workers to 30 junior workers;
- (vi) Scheme for promotion and employment of employees after demotion: 12 employees will be restored after senior workers are demoted to junior workers in the second year. In the third year, 11 intermediate workers were reinstated after being demoted to primary workers, and 64 senior workers were reinstated after being demoted to primary workers.

5.2. Discussion

The main goal of this paper is to create the maximum net profit according to the existing human resources. Then, according to the human resource planning in the next three years, the optimal allocation scheme of the minimum dismissal model and the minimum cost model is obtained.

The research results can effectively guide the human resource management of the operation and maintenance project of the Shuohuang Railway Company, and have important theoretical and practical significance for further analysis of the human resources model and its optimal allocation method.

Because there are many uncertainties in the future transportation conditions, the possible changes in transportation elasticity and external costs are not considered in this paper. The authors will consider these uncertainties in future studies.

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