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Procedia Computer Science 112 (2017) 1611–1622

Procedia Computer Science

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# An Inverse Optimization Model for Human Resource Allocation Problem Considering Competency Disadvantage Structure

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**Abstract**

Most of serious and major accidents that happened during the production procedure of process industry are caused by improper equipment operations, which is further owing to inappropriate human resources allocation and ignorance of individual competencies differences. In order to take both of competency disadvantage and adjustment requirement into consideration, we use an inverse optimization method to solve a human resource allocation problem, and furthermore, adjust equipment operating parameters to make the per-defined settings optimized, such as the total number of jobs, security-related parameters and so on.In the solving process, firstly a standard competence hierarchy system is conducted; secondly we propose an assessment method according to disadvantage structure; thirdly we use inverse optimization method to solve the problem and optimize the predefined allocation plan. Lastly, we give an example to prove its feasibility and effectiveness. In this paper a novel formulation of human resource allocation problem is proposed, in which some of main individual characteristics are considered and described mathematically, including psychology, behaviour and characteristics diged from them such as weakness. The other contribution of this paper is using inverse optimization to adjust parameters based on the given ideal allocation plan. Both of these propositions have a positive significance on promoting development and security construction for process industries.This research incorporates the academic thinking of inverse optimization, it not only puts psychology and behavior into optimization model, but also data mines weakness characteristics under the psychology and behavior data, and find a new way to introducing the weakness characteristics into decision making model. It provides a new thought for the following decision making problem, that is the ideal decision plan is known, and optimization parameters are changeable. It promotes the combining of psychology, behavior and operations research, it is good for process industries to develop in a safety and efficiency way.

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*Keywords:* inverse optimization; linear programming; human resource allocation; competency; evaluation according to disadvantage structure

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Peer-review under responsibility of KES International
10.1016/j.procs.2017.08.248

## 1. Introduction

Process industry includes petrochemical industry, iron and steel industry, nuclear power industry and so on. All of thses process industries are very important to the development and security of the country. Process industries partly deploy continuous production, the manufacturing process always goes with a series of physical changes and chemical reactions, which makes the whole production process very dangerous due to its inflammable and explosive properties. so security is the first concern for the whole equipment and human resources management in process industry. The production safety degree mainly relies on human resources competency with consideration of disadvantage, and most importantly, it depends on the allocation of human resources. The equipment operation competency always implies specific characteristics that differentiate competent operators from poor or normal ones. Competency management research of process industries still lag behind in the reality need. This issue is most noticeable at the human resources allocation and adjustment planning level. Human resources allocation of process equipment is inclined to use mathematical optimization methods, such as linear programming, nonlinear programming, multi-object programming, combinatorial optimization, integer programming, apply these models to achieve the best economy benefit under the constrains of workload needed with consideration of efficiency. Furthermore, most of the human resources optimization methods propose an optimization model under the condition of the known cost parameters, workload parameters, efficiency parameters, through some algorithm, to determine the value of decision variables( for example resources allocation plan), to achieve the goal of cost as small as possible or the profit as large as possible.

There are some particular characteristics of equipment operators, firstly, work efficiency depends on competency; secondly, equipment operation system security follow the "cask principle", an equipment operation system's safety depends on the weakest point which is worker's comprehensive evaluation of competency according to the disadvantage structure. In terms of extending cask principle, with consideration of equipment safety operation, we define work efficiency parameter in the optimization model as the average competency evaluation result according to disadvantage structure. Disadvantage structure is defined as the evaluation weight vector which can make the object achieve worst result. Also according to the characteristics of human resources, we integrate behavioral factors and psychological factors into optimization model.

However, in reality, sometimes the human resources allocation plan is determined, for example, the plan is an order from the top leader, under the pressure of human resources reform such as cutting down the number of person employed, so the resources allocation decision has to follow the order. Then this is a pre-set plan-driven human resources allocation problem, this problem has been on the rise in resources management practice. Also in the real world, human resources allocation problem always face the challenge on revealing unknown or implicit parameters in decision-making processes. But we can estimate parameters with experiences. In order to solve this kind of problem, the decision maker needs to change some of the model parameters to make the predefined resources plan the optimal solutions under the new parameters. This problem is through adjusting optimization model parameters to make the pre-set plan be the optimal solutions. All these problem features agree with the definition of inverse optimization. Inverse optimization consists of finding a minimal adjustment of the parameters such that a given set of feasible solutions become optimal. Especially, behavior and psychology features are very important to equipment operation safety, so in this work, an inverse optimization model is developed for allocating human resources to different jobs with consideration of psychology and behavior features. The adjusted parameters refers to the work load parameters. The cost parameters are determined according to average salaries, the efficiency parameters are determined by the comprehensive competency evaluation according to disadvantage structure. The decision variables express the number of personnel allocate to different job groups.

The paper is divided into four main sections. The next section provides a literature review, section 3 proposes a competency indicator model of equipment operation personnel and construct a comprehensive evaluation model based on disadvantage structure. Section 4 proposes the inverse optimization method for human resources allocation with consideration of psychology and behavior. To my best knowledge, this paper was the first instance using the inverse optimization approach for human resources allocation with a focus on determining the implicit value associated with the competency condition, and in order to make the idea plan to be the optimal solution after parameter revised. The last section is to propose an application example to demonstrate the reliability and feasibility.

## 2. Literature review

(1) Competence model and evaluation literature review：There are many significant research on competence models Competencies refer to the combination of knowledge, skill, morality, ideas and so on. Competence is defined from different perspectives such as general competences, soft skills technical competencies. With the development of multivariate analysis method, competency modelling has a standard framework and method. Furthermore, competency models have been developed widely used to identify competencies required to perform a specific job effectively in an organization. The competency includes: delivery-related competencies, interpersonal competencies, strategic competencies, communication skills, resource-information-technology processing and application skills, interpersonal and cooperative skills, global competency, comprehensive thinking competency, self-management competency, reading for information competency, applied mathematics competency, problem solving competency, critical thinking competency, managing personal and interpersonal relationships competency, communication competency. The competencies related to safe operation includes: perceived susceptibility, perceived severit, perceived benefits of taking action, perceived barriers to taking action cues to action, self-efficacy[1]. Competency evaluation is the foundation of competency-based human resources allocation. There are lots of evaluation method developed in recent years. There has been wild research on quantitative methods, for example: AHP method, DEA method, Mixed-Methods, Fuzzy AHP, Evaluation according to strengths, evaluation from a multilevel perspective. Evaluation method is always along with specific problem, according to the characteristics of the problem, the specific evaluation method is proposed.

(2) Human resources optimization literature review：There are lots of progress on the research of human resources optimization method. Such as top-down and bottom-up approach [2]. 0-1 assignment model[3]. multi-project human resource allocation based on the negotiation mechanism with consideration of total cost constraint and individual disciplines [4]. call center human resource allocation model according to M / M / N + M queuing model[5]. “ four-in-one ” personnel matching method based on advantage structure[6]. fuzzy input-output optimization model[7]. optimal human resource management model with consideration of total utility level or cost input condition[8].

(3) Human resources optimization literature review：There are mainly two kinds of inverse optimization problems, the general inverse (reverse) optimization problem and inverse optimal value problem, each kind of problem has been researched from the perspective of modeling, algorithm and application. Generally, inverse optimization is given an ideal solution, in order to make the ideal solution be the optimal solution, through adjust the original model parameters as small as possible and meet the demand of the ideal solution optimal. The research mainly focus on the following problems: 1) Under some specific assumptions, the demonstration of the existence of optimal solution; 2) the convert method from forward optimization, such as linear programming model, multi-objective programming, assignment model, nonlinear programming, match problem and so on. According to the

mathematical characteristics of each programming model, the convert method of each type of optimization model has been studied. And different optimization algorithms and evolutionary algorithms to solve different inverse optimization models. From the perspective of application research, most of the applications are used for estimation of parameters in the original optimization model. Such as given a linear program, a desired optimal objective value or decision plan, and a set of cost vectors, resources vectors, efficiency matrix, one needs to determine a cost vector of the linear program such that the corresponding optimal objective value is closest to the desired value or desired decision plan. The representative achievements are: shortest path inverse optimization problem[9]. restricted inverse optimization model with a value coefficient not allowed to adjust [10]. generalized inverse optimization model of linear programming for optimal production planning [1]. inverse optimization model of linear programming on logistics center [11]. inverse optimal allocation model in grid environment [12]. inverse optimization for security resource allocation [13]. inverse linear programming model of interval coefficient [14]. inverse optimization method to determine heating mode [15]. inverse packing problem[16]. inverse optimization of supply chain resources [17]. security resource allocation[13]. portfolio selection through inverse optimization [18]. inverse data pack analysis of the frontier changes of target setting " [19].

There are lots of researches on the topics of human resources management, comprehensive evaluation method and inverse optimization method, these researches give this study a lot of enlightenment. However, so far as we know, there is no research which combines competency, disadvantage structure and inverse optimization together, and the combination is very important for equipment operation safely in process industries. So we focus on disadvantage competency-based human resource inverse allocation method. This research incorporates the academic thinking of inverse optimization, and not only puts psychology and behavior parameter into optimization model, but also identify disadvantage structure under the psychology and behavior data, and find a new way to introducing the disadvantage characteristics into optimization model. So we study the above problem, it is beneficial for broadening the research methods of decision making problems; it promotes the combining of psychology, behavior and optimization research, it is good for process industry enterprises balance safety and benefit, it is good for process industries to develop in a health way.

## 3. Equipment operator competency evaluation according to disadvantage structure

The comprehensive evaluation method contains three parts: (1) construct a competency indicator system; (2) construct a disadvantage structure identification model; (3) construct a comprehensive model based on disadvantage structure parameters.

### *3.1. Equipment operation competency indicator system*

We construct a competency indicator system to improve equipment operation safety in process industry from a human-centered perspective. Equipment operation competency model describes a statistic analysis result. It can be used todistinguish highly effective workers from ordinary or low performance workers. The formation of equipment operation competency indicator system follows three steps belowas mentioned in related literatures : brain storm method and Delphi Method, analysis of the questionnaire's reliability and validity. The questionnaire was conducted on 244 employees randomly selected from three different process industry companies. A total of 500 persons were approached and 256 returned. After removing 12 incomplete questionnaires, we obtained a sample of 244 respondents. We measured all the variables considered with multiple-item scales. We use Likert scale method to measure the level of agreement. We use a structural equation model approach with AMOS software. We tested the reliability of each construct by using Cronbach's Alpha. To test the convergent validity of the measures, we examined the significance of the factor loading to prove reliability.The KMO and Bartlett is shown in table 1.

Table 1 Competency of KMO and Bartlett

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin | | .960 |
| Bartlett vale | approximate chi-square | 20187.717 |
| | df | 1653 |
| | Sig. | .000 |

The regression coefficient of measurement model of equipment operator competency is shown in table 2.

Table 2 Regression coefficient of measurement model

| indicators | regression | factor | path coefficient | S.E. | C.R. | P | Standard path coefficient |
|---|---|---|---|---|---|---|---|
| collaboration | <--- | psychology | 1.000 | | | | .880 |
| act decisively | <--- | psychology | 1.036 | .054 | 19.286 | *** | .833 |
| sharing | <--- | psychology | .985 | .049 | 19.926 | *** | .849 |
| self-control | <--- | psychology | .927 | .050 | 18.420 | *** | .811 |
| detail oriented | <--- | attitude | 1.000 | | | | .841 |
| logic | <--- | attitude | 1.128 | .059 | 19.076 | *** | .869 |
| profession | <--- | attitude | 1.074 | .057 | 18.783 | *** | .860 |
| responsibility | <--- | attitude | .946 | .056 | 16.888 | *** | .803 |
| problem solving | <--- | skill | 1.000 | | | | .825 |
| systematic thinking | <--- | skill | 1.221 | .064 | 19.025 | *** | .875 |
| innovation ability | <--- | skill | 1.180 | .070 | 16.739 | *** | .804 |
| risk management | <--- | skill | 1.166 | .061 | 18.979 | *** | .873 |
| analytical skills | <--- | skill | 1.023 | .060 | 16.944 | *** | .810 |
| technology | <--- | knowledge | 1.000 | | | | .831 |
| mechanism | <--- | knowledge | .981 | .052 | 19.025 | *** | .872 |
| production process | <--- | knowledge | .980 | .054 | 18.201 | *** | .847 |
| automatic system | <--- | knowledge | 1.011 | .053 | 18.949 | *** | .870 |

*3.2. Competency evaluation method according to disadvantage structure*

*Definition:* disadvantage structure is the evaluation indicator weight vector, which is based on the evaluation competency system, according to the evaluation object´s actual indicator value, construct an optimization method, the decision variable is weight vector, the objective is to get the worst evaluation result of the evaluation object, the parameter is evaluation indicator value.

*Symbol description:* Competency evaluation model is expressed by a three layer indicator system. The top level is competency $z$ , the middle level competency indicator is $y_t, t=1,2, \quad ,i, \quad m$, which means $y_1, \quad ,y_i, \quad y_m$, the weight vector is $\mu_t, t=1,2, \quad ,i, \quad m \ \mu_1, \quad ,\mu_i, \quad \mu_m$. $y_1$ contains basic indicator $x_{11}, x_{12}, \quad ,x_{1p_1}$; $y_i$ contains basic evaluation indicator $x_{i1}, x_{i2}, \quad ,x_{ip_1}$ . $y_m$ contains basic indicator $x_{m1}, x_{m2}, \quad ,x_{mp_m}$ , corresponding evaluation weight vector is $\lambda_{m1}, \lambda_{m2}, \quad ,\lambda_{mp_m}$ .Competency system can be expressed as figure 1.

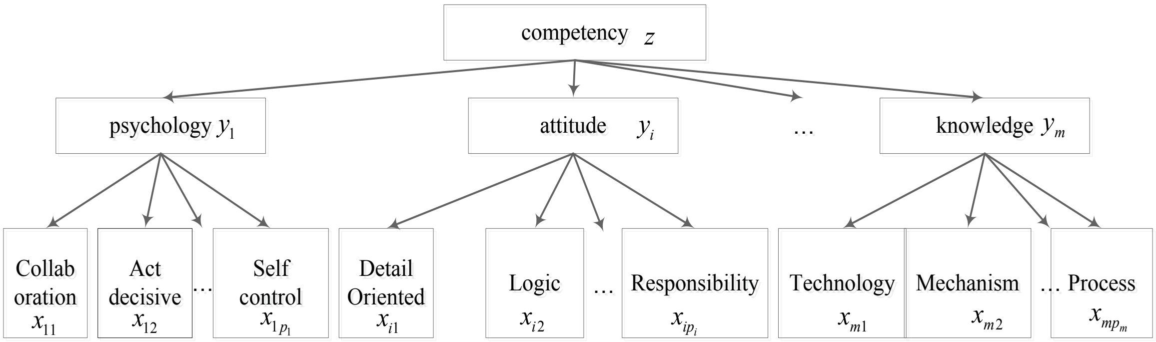


Figure 1: Equipment operation competency indicator system

(1) Disadvantage structure identification method of middle level identification method according to the basic level indicator value.

$$\min_{\lambda} d_t^{(i,k)^2}\left(x_{(t,j)}^{*+} - x_{(t,j)}^{(i,k)}\right) = \sum_{j=1}^{p_t}\left(\lambda_{(t,j)}^{(i,k)}\right)^2\left(x_{(t,j)}^{*+} - x_{(t,j)}^{(i,k)}\right)^2$$

$$s.t. \ \sum_{j=1}^{p_t}\lambda_{(t,j)}^{(i,k)} = 1 \qquad (1)$$

$$\lambda_{(t,j)}^{(i,k)} \geq 0 \quad j=1,2, \quad ,p_t$$

The objective minimizes total competency benefits. Subject defines the weight restriction. $x_{(t,j)}^{*+}$ is the positive ideal value of indicator, for example, if the value is expressed by Likert five scale method, $x_{(t,j)}^{*+}$ equals to 5.

$x_{(t,j)}^{(i,k)}$ is indicator value, which is an known value by 360 degree appraisal law.

(2) Competency evaluation in the middle level according to disadvantage structure $y_t$ is model(2).

$$y_t \begin{cases} =0\ ;\ if \quad x_{ti} \neq x^*_{ti} \\ =\sqrt{\sum_{j=1}^{p_t} \left(\lambda_{(t,j)}^{(i,k)}\right)^{(*+)2} \left(x_{(t,j)}^{*+} - x_{(t,j)}^{(i,k)}\right)^2}\ ; \quad otherwise \end{cases} \tag{2}$$

When all the basic indicator of the $t$ th middle level indicator is ideal, the value of $y_t$ is 0. Otherwise, the value of $y_t$ is calculated according to distance function.

(3) Disadvantage structure identification mode from the top level.

$$\begin{aligned} &\min_{\mu} d_t^{(i,k)^2} (y_t^* - y_t^{(i,k)}) = d_t^{(i,k)^2} (0 - y_t^{(i,k)}) \\ &= \sum_{t=1}^{m} (\mu_t^{(i,k)})^2 \sum_{j=1}^{Pt} (\lambda_{(t,j)}^{(i,k)^*})^2 (x_{(t,j)}^* - x_{(t,j)}^{(i,k)})^2 \\ &s.t. \sum_{t=1}^{m} \mu_t^{(i,k)} = 1 \\ &\mu_t^{(i,k)} \geq 0 \\ &t = 1, 2, \quad , m \end{aligned} \tag{3}$$

$\mu_t^{(i,k)*}$ is the disadvantage structure identification result.The objective minimize total competency benefits. Subject defines the weight restriction. $y_t^*$ is the positive ideal value of indicator, in this case $y_t^*$ equals to 0. $\mu_t^{(i,k)*}$ is optimal solution, represents disadvantage weight parameter of the middle level.

(4) Competency evaluation method based on disadvantage structure

The value of top level competency indicator is calculated according to model (4).

$$\begin{aligned} D(z) &= \sqrt{\sum_{t=1}^{m} (\mu_t^*)^2 (y_{(t)}^* - D(y_t))^2} = \sqrt{\sum_{t=1}^{m} (\mu_t^*)^2 (D(y_t))^2} \\ &= \sqrt{\sum_{t=1}^{m} (\mu_t^*)^2 [\frac{1}{n} \sum_{i=1}^{n} \sqrt{\sum_{j=1}^{pt} (\lambda_{(t,j)}^*)^2 (x_{(t,j)}^* - x_{(t,j)}^{(i,k)})^2}\ ]^2} \end{aligned} \tag{4}$$

The average result of each personnel at each job is the efficiency parameter value.

## 4. Inverse optimization of human resources allocation based on competency disadvantage structure

Opposite to the forward minimize cost approach, an inverse approach was undertaken to infer the values of model workload parameters to make the desired human resources allocation plan the optimal solution under new parameters. Human resources optimization problem is to determine the values of decision variables such that the objective function can get the optimal value on the condition that all parameters are given in the optimization model of objectives and constraints. In this research, efficiency parameter value is calculated according to competency evaluation according to disadvantage structure. The cost parameter is calculated according to human resources salaries and the enterprise actual situation. The constrain parameters are total working hour need for each job. The objective function of optimization is the make the cost as small as possible. The decision variable is working hours allocation plan of each kind of human resources to each kind of job.

### *4.1 Forward optimization model of human resources optimization*

The necessary and function of the original model are the follows: 1) it is a description of the specific human resources allocation problem, in the original model, we do not care whether the optimal solution has an actual meaning or the parameters are known, we just want to give a description of the human resources system; 2) it is a basic model of converting, which means the starting point for inverse optimization.

The general optimization model is as following model(5), The standard model is the basis for converting the original model, because the converting method is according to dual theory, so if we give the standard model, it is convenient for converting:

$$\min Z = f(x)$$
$$\text{s.t.} \quad x \in \Omega \tag{5}$$

$$\Omega = \left\{ x \in R^n \,\middle|\, A_i(x) = 0, i \in E; A_i(x) \geq 0, i \in \Gamma \right\}$$

In order to simplify the problem and also according to the investigation, we construct a linear programming model, it can be formulate as model(6).

$$\min Z = \sum_{j=1}^{n} c_j x_j$$
$$s.t. \begin{cases} \sum_{j=1}^{n} a_{ij} x_j \geq b_i, i = 1, \ldots\ldots, m \\ x_j \geq 0, j = 1, \ldots\ldots, n \end{cases} \tag{6}$$

Therein, the decision variables are $x_j$, the cost vector is $c_j$, the efficiency parameter is $a_{ij}$, the resource vector $b_i$, and $b_i \geq 0$, the object is to make the human resources cost as small as possible. There are $n$ jobs, $m$ human resources.

*4.2 Inverse optimization model converting method*

According to the optimization model of problem description, choosing adjusted parameters, in this case we change work load parameter as small as possible, After all this, we can achieve the goal of the new human resources allocation plan meets the requirement of reform, and make the plan guarantee the competency satisfy the requirement of operation safety and reliable, also it can meet the cost requirement.

The solving method of the inverse optimization depends on the mathematical characteristics of the inverse model, different inverse optimization models need different solving methods. We use Lingo to solve the original model for the following reasons: 1) we want to compare the results with inverse optimization model. Dual model is theoretical basis for converting from forward model to inverse optimization model.

According to dual theory, the inverse optimization is (7) and (8).

Inverse human resources optimization consists of finding a minimal adjustment of $b_i$ such that a given set of feasible solutions becomes optimal. When we adjust $b_i$, The inverse optimization model is:

$$\min \left\| \bar{b} - b \right\|$$

$$s.t. \begin{cases} a_i . \bar{x} \geq \bar{b}, w_i = 0 \\ a_i . \bar{x} = \bar{b}, w_i > 0 \end{cases} \tag{7}$$

Let $\bar{b}_i = b_i + \sigma_i - \beta_i$, $i = 1, 2, ......m$, $\sigma_i \geq 0$, $\beta_i \geq 0$ $\left\| \sigma_i - \beta_i \right\| \leq \left\| \sigma_i - \beta_i \right\|$, model (7) equals to model(8)

$$\min \left\| \sigma + \beta \right\|$$

$$s.t. \begin{cases} a_i . \bar{x} - \sigma_i + \beta_i \geq \bar{b}, w_i = 0 \\ a_i . \bar{x} - \sigma_i + \beta_i = \bar{b}, w_i > 0 \\ \sigma_i, \beta_i \geq 0, i = 1, 2, ......m \end{cases} \tag{8}$$

**4. Case study**

An inverse optimization problem can be described as follows: Given an optimization problem(which is original optimization model) and a feasible solution to it, the corresponding inverse optimization problem consists of finding a minimal adjustment of the vector such the given solution becomes optimum.

In corresponding to model(6), we define the adjusted parameters B are the work load parameters. The cost parameters C are determined according to average salaries, the efficiency parameters A are determined by the comprehensive competency evaluation according to disadvantage structure. The decision variables X express the hours of each kind of human resources allocate to different job groups.

There are 4 kinds of jobs, there are 3 kinds of human resources, the cost vector for each kind of human resources isC=(15,10,20)， the total work load needed $B=(7,16,9,8)^T$, the forward optimization problem is modeled as expressions (9).The first X is calculated according to the original model, it is the optimal solution of the original model. The x* is a pre-set resources plan, it is a given solution, it is given by the authority, it is not a calculated result.

$$\min Z = 15y_1 + 10y_2 + 20y_3$$
$$\begin{cases} 3x_{11} + x_{12} \ge 7 \\ 2x_{21} + 3x_{22} + 4x_{23} \ge 16 \\ x_{32} + 3x_{33} \ge 9 \\ 2x_{41} + 2x_{43} \ge 8 \\ y_1 = x_{11} + x_{21} + x_{31} + x_{41} \\ y_2 = x_{12} + x_{22} + x_{32} + x_{42} \\ y_3 = x_{13} + x_{23} + x_{33} + x_{43} \\ x_{ij} \ge 0 \end{cases} \tag{9}$$

Using Matlab to solve model (9), the optimal solution of model (9) is:

$$X = \begin{bmatrix} 2 & 1 & 0 \\ 3 & 2 & 1 \\ 0 & 3 & 2 \\ 2 & 0 & 2 \end{bmatrix}, Y = (7,6,5), Z = 265 \tag{10}$$

In practical applications, given the solution (11), the decision maker need to make (11) the optimal solution according to reality concerns.

$$X^* = \begin{bmatrix} 3 & 1 & 0 \\ 3 & 2 & 1 \\ 0 & 3 & 2 \\ 2 & 0 & 1 \end{bmatrix} \tag{11}$$

We use inverse optimization to adjust B. Then the inverse optimization model is as follows:

$$\min \theta_1 + \theta_2 + \theta_3 + \theta_4 + \alpha_1 + \alpha_2 + \alpha_3 + \alpha_4$$
$$\begin{cases} 9 + 1 - \theta_1 + \alpha_1 \ge 7 \\ 6 + 6 + 4 - \theta_2 + \alpha_2 \ge 16 \\ 3 + 6 - \theta_3 + \alpha_3 \ge 9 \\ 4 + 2 - \theta_4 + \alpha_4 \ge 8 \\ \theta_i, \alpha_i \ge 0, i = 1,2,3,4 \end{cases} \tag{12}$$

To solve model(12), the optimal solution is $\theta = (3,0,0,0)^T$ , $\alpha = (0,0,0,2)^T$

Under the above parameters, the optimal solution of model (12) is $X^*, Y=(8,6,4), \quad Z=260$

Through the case study, we indicate that according to the forward optimization model(9), a given solution (11), through inverse optimization by adjust B as minimum as possible, we can get a better result $Y=(8,6,4), \quad Z=260$ than the original optimization problem $Y=(7,6,5), Z=265$

## 5. Conclusions

This study adopts the linear programming method to a human resources allocation model with consideration of competency disadvantage structure by the logic of "competency indicator system→competency evaluation method based on disadvantage structure →optimization model →inverse optimization converting→ solution" .

The main contribution of the article is as follows: firstly, we propose a method which can introduce psychology and behavior features into optimization model; secondly, we propose a new method which can solve the problem whose ideal solution is known, we try to make the ideal solution the optimimal solution with the method of adjust the optimization parameters, and with consideration of the stability of the original system(described by forward optimization model), we claim that the adjustment is as small as possible. Thirdly, this method solves the problem of the forward optimization parameters are unknown or changeable, but we can give a estimation value according to experience, what we need to do is to determine the parameter value. It promotes the combining of psychology, behavior and operation research, it is good for process industries to develop in a safety and efficiency way.

## Acknowledgements

The research work was supported by Youth Project of National Natural Science Foundation (71401023), Youth Project of Humanities and Social Sciences Fund of Education Ministry (14YJC63019), China Postdoctoral Science Foundation(2017M610831),Liaoning Province Social Science Association (2017lslktyb-049) and Dalian City Social Science Association (2016dlskyb013).

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