



Assignment of employees to workplaces under consideration of employee competences and preferences

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Abstract

Purpose – This paper seeks to develop a model for the assignment of employees to workplaces. Assignment methods are of high relevance in practice because employees should be assigned to workplaces according to their competences and preferences to ensure that motivated employees carry out tasks effectively and efficiently.

Design/methodology/approach – Two goal programming models are introduced with inputs and valuations using the analytic hierarchy process.

Findings – The two goal programming models for the assignment of employees to workplaces, which take into account both employee competences and preferences as well as workplace competence requirements and attributes, seem to be effective in helping to arrive at an optimal assignment decision.

Research limitations/implications – In practice, one major problem is that the input data for the goal programming models are not updated regularly. Thus, the documentation of the competence profiles and the preferences of the employees might be out of date or incomplete.

Originality/value – The development of the two goal programming models which could be applied immediately in practical competence management is what makes the work valuable and addresses a gap in the modelling of personnel assignment methodologies.

Keywords Competences, Skills, Workplace, Employee attitudes, Analytical hierarchy process, Programming

Paper type Research paper

1. Introduction

Much research has been done on the documentation and inquiry of competences. Much effort has been devoted to the conceptualization of ontologies with the aim to overcome linguistic divergences between semantically equivalent information from different sources (Hefke and Stojanovic, 2004; Lau and Sure, 2002; Sure *et al.*, 2000) and the computer-based automatic inquiry of competences using non-deductive inference rules (Dittmann and Zelewski, 2004). In practice, several software systems have been developed that offer functions dedicated to the documentation of competences (Primavera Systems, Inc., 2006; SAP AG, 2006). Such software systems enable the user to find employees with specified competences quickly. But the competence-based assignment of these employees to workplaces is not supported by any commercially available software system. Also, relatively little research has been done on this topic (Peters and Zelewski, 2005). However, the assignment of employees to workplaces can lead to ineffective and inefficient job performance for several reasons. On the one hand, employees probably might not satisfy the competence requirements associated with the workplaces to which they have been assigned and, as a result, they cannot cope with workplace strains. Employees should therefore be assigned to workplaces according to their competences to ensure effective and efficient job performance. On the



other hand, employees may have been assigned to their workplaces against their preferences regarding the competences and the general conditions of the workplace.

Non-fulfillment of competence requirements as well as assignment contrary to employee preference may easily lead to employee demotivation. Firstly, workplace assignment based upon individual competences enables the employees to select the appropriate activities to perform the tasks. As a result, they are able to complete their tasks more easily. Secondly, the consideration of competence preferences leads to higher motivation since employees are normally more motivated to complete tasks related to their interests and abilities. Moreover, this consideration affords employees the opportunity to rank their interests and abilities. An employee might prefer to speak Spanish rather than Italian, for example. Such an employee would prefer a workplace with a higher relative importance of the competence “Spanish language knowledge” in comparison to the competence “Italian language knowledge”. Thirdly, the consideration of preferences regarding general workplace conditions also leads to higher motivation. For example, a mother raising children on her own may prefer a workplace with a reduced number of work hours per day or reduced work days in a week.

2. Terminological preliminaries

2.1 *Competences, competence hierarchies, competence profiles, and competence levels*

A competence can be defined as the ability of an employee to utilize his or her knowledge to achieve a predefined goal, such as an effective and efficient execution of a task (Peters and Zelewski, 2005). An example of a competence is an employee’s ability to use his or her language knowledge to negotiate with foreign business partners.

Competences can be structured in a so-called competence hierarchy. In such a hierarchy, similar competences are grouped under a node. The competences “Italian language knowledge”, “French language knowledge”, and “Spanish language knowledge”, for example, may be grouped under the node “foreign language knowledge”. Furthermore, competence profiles are suitable for the documentation of competences. On the one hand, employee competence profiles are required to document the competences of each employee. An employee’s competence profile consists of a certain set of competences and an assessment of how well an employee meets each competence. The competences require assessment because the level of proficiency in each competence (employee competence level) may vary from employee to employee. One employee might reach a higher level of proficiency in the competence “Italian language knowledge” than another, for example. How well an employee meets each competence may be assessed using a normal ordinal scale with levels ranging from 1 (dilettante) to 5 (expert). Other scales may be more appropriate (e.g. scales with 9 levels), depending on the desired degree of detail. Enterprise Resource Planning Systems (SAP AG, 2006) and Project Management Systems (Primavera Systems, Inc., 2006) provide appropriate functions. A refinement of this assessment technique is presented below in section 3.

On the other hand, workplace requirement profiles are needed to document the minimum or specific fixed competences required for each workplace. A requirement profile has to be created for each workplace using the same ordinal scale. Each workplace requirement profile encloses a minimum or specific fixed level of proficiency for each competence. Moreover, a workplace requirement profile contains an assessment of the importance of a competence to a workplace.

2.2 Workplace attributes, attribute hierarchies, and attribute profiles

Workplace attributes describe the general conditions associated with a workplace: “hours of work per day”, “number of work days in a week”, “operational safety”, “air pollution”, “noise pollution”, “building security”, “communications equipment”, and “office space” serve as examples of such attributes.

Analogous to competences, workplace attributes can be structured in an attribute hierarchy. For example, the workplace attributes “building security”, “communications equipment”, and “office space” may be grouped under the node “location attributes”.

All workplace attributes with the accompanying attribute values describing a certain workplace can be combined into a workplace attribute profile. The preferences of each employee for specific attribute values can be combined into an employee attribute profile in the same way.

3. The analytic hierarchy process

The goal programming models presented here require several assessments. For example, the employees have to assess their preferences. Moreover, the relative importances of the competences to the workplaces have to be assessed. These assessments can be undertaken using the analytic hierarchy process (AHP) which was introduced by Saaty (1994, 2000, 2001). The standard AHP requires paired comparison judgments concerning the dominance of one element (e.g. to assess the importance of a competence to a workplace) over another with regard to an explicitly specified evaluation criterion for each of a set of elements using a 1-9 scale, in order to obtain an importance weight for each element. The paired comparison judgments are entered in a square matrix A . If an element i is judged to be moderately important by comparison with another element j , for example, a 3 is entered as the value for the paired comparison judgment a_{ij} in the matrix A while the reciprocal value is entered for the paired comparison judgment a_{ji} . The importance weights are derived by computing a normalized eigenvector v_{norm} of the pair wise comparison matrix A . This is what is called the relative measurement mode of the AHP. Furthermore, the AHP offers the opportunity to check the consistency of judgments in a matrix. Saaty defines a matrix A to be consistent, if the following condition is satisfied (Saaty, 2000):

$$a_{ik} * a_{kj} = a_{ij} \quad \forall i, j, k = 1, \dots, n \quad (1)$$

The essential idea of the AHP is that a matrix A of rank n is only consistent if it has one positive eigenvalue $\lambda_{\text{max}} = n$ while all other eigenvalues are zero (Saaty, 2000). Moreover, Saaty developed the consistency index (C.I.) to measure the deviation from a consistent matrix (Saaty, 2000):

$$\text{C.I.} = \frac{\lambda_{\text{max}} - n}{n - 1} \quad (2)$$

The consistency ratio (C.R.) is introduced to aid the decision on revising the matrix or not. It is defined as the ratio of the C.I. to the so-called random index (R.I.) which is a C.I. of randomly generated matrices (Saaty, 2000):

$$\text{C.R.} = \frac{\text{C.I.}}{\text{R.I.}} \quad (3)$$

For $n = 3$ the required consistency ratio should be less than 0.05, for $n = 4$ it should be less than 0.08 and for $n \geq 5$ it should be less than 0.10 to get a sufficient consistent

matrix (Saaty, 2000). Otherwise the pair wise comparison matrix should be revised. Making pairwise comparison judgments in a model that has a large number of elements (e.g. competences, preferences) can be very time consuming. Accordingly, if a large number of elements is considered, it could be practical to create a hierarchy of the elements. A hierarchy of the elements can be used to reduce the number of pair wise comparisons judgments. On the other hand, it can be helpful to have well-structured elements.

An extension of the AHP, the so-called absolute measurement mode, is suitable for assessing competence levels (Saaty, 1994). The absolute measurement mode represents a refinement of normal ordinal scales. Analogous to normal ordinal scales, competence levels are assigned to employees and workplaces. But moreover, the absolute measurement mode offers the opportunity to make judgments about how much one competence level is preferred to another utilizing pair wise comparison judgments. For example, a human resource manager may judge a competence level “dilettante” to be weakly preferred to a competence level “average” as well as he may judge a competence level “expert” to be strongly preferred to a competence level “dilettante”. These preference judgments have to be entered into a pair wise comparison matrix. For each of those competence levels a numerical value is derived by computing a normalized eigenvector of the pair wise comparison matrix. Moreover, the absolute measurement mode of the AHP can also be employed to assess some workplace attributes. For example, the absolute measurement mode can be utilized to assess the preference for different levels of “operational safety”.

4. The goal programming technique

Charnes and Cooper (1961) introduced the term “goal programming”. It is a mathematical programming technique designed to handle multiple conflicting objectives. The utilization of its models has spread in many, diversified fields of interest, such as site selection (Hoffman and Schniederjans, 1994), resource constraint project scheduling (Mohanty and Siddiq, 1989), resource allocation in health care systems (Azaiez and Al Sharif, 2005; Kwak and Lee, 1977), premium planning in the insurance industry (Heras *et al.*, 2002), and project selection (Mukherjee and Bera, 1995), just to name a few. In goal programming, the desired level of fulfilment of each objective is viewed as a goal. The technique enables a decision maker to consider one-sided goals and two-sided goals. If the objective is to reach or exceed a one-sided goal, it is called a lower one-sided goal; otherwise, if the objective is to reach or fall below a one-sided goal, it is called an upper one-sided goal. If the objective is to meet a goal as closely as possible, it is called a two-sided goal (Hillier and Lieberman, 2001).

The aim of the application of goal programming is to minimize the deviations of the goals considered. So-called deviational variables measure the amount by which the values delivered by the solution of the goal programming model deviate from the respective goal. If a lower (an upper) one-sided goal is considered, the objective function will contain a non-negative underachievement (overachievement) variable (e.g. Kwak and Lee, 1997). If a two-sided goal is considered, the objective function will contain both an underachievement and an overachievement variable. Further, the basic goal programming model can be enhanced by considering differences in the relative importance of goals. This enhanced approach is named weighted goal programming and assigns importances to the underachievement or overachievement variables according to their relative importances. Moreover, two types of goal programming models are differentiated: the preemptive case and the non-preemptive case (e.g. Hillier

and Lieberman, 2001). In preemptive goal programming models different objectives are prioritized as first-priority-goals, second-priority-goals, third-priority-goals, and so on. In an initial step a first part model is solved which only incorporates the first-priority-goals. If the execution of the initial step leads to more than one optimal solution of the first part model, a second part model incorporating the second-priority-goals is solved keeping the optimal achievement-level of first-priority-goals constant. As long as the execution of a step leads to more than one optimal solution of the respective part model and as long as there are goals of lower priority defined, a further part model is applied in an additional step. Lower-priority-goals are not considered unless the higher-priority-goals are optimally satisfied and this optimal solution is many-valued. By contrast, in non-preemptive goal programming models, different objectives are considered simultaneously as goals in an aggregated objective function. If solving a non-preemptive goal programming model or a preemptive goal programming part model in the lowest step delivers multiple optimal solutions, a tie breaking rule (e.g. sample selection) can be employed to select one of these solutions.

5. The goal programming models for workplace assignment

5.1 Collection of input data for the goal programming models

The goal programming models presented here offer the opportunity to consider three different objectives:

- (1) assignment of employees to workplaces according to the fit of their actual and the required levels of competence, respectively;
- (2) assignment of the employees to workplaces according to the fit of their preferences regarding the competences and the relative importances of the competences to the workplaces; and
- (3) assignment of the employees to workplaces according to the fit of their preferences regarding the general conditions of the workplace and the actual values of workplace attributes.

The first step is to assess the relative importances of the three fore mentioned objectives employing the relative measurement mode of the AHP. In the preemptive goal programming model presented below, the first objective is considered as single first-priority-goal, while the second and the third objectives are considered as second-priority-goals. The preemptive goal programming model requires the assessment of the relative importances u_2 and u_3 of the second and the third objective. In the non-preemptive goal programming model all three objectives are considered simultaneously as first-priority-goals. Thus it requires the assessment of the relative importances u_1 , u_2 , and u_3 of all three objectives. If an objective is not to be considered, it has to be assigned a value of zero for its respective importance u_1 , u_2 , or u_3 . Only the preemptive goal programming model enforces the consideration of the first objective, because the importance u_1 could be set to zero. If the first objective is not to be considered, only the non-preemptive goal programming model can be utilized. As a rule of practical relevance, however, the highest importance value should be assigned to u_1 , since the employees have to be enabled by their competence levels to select the appropriate activities to perform the tasks at the respective workplaces.

In the second step, it is necessary to assess the actual competence levels for each competence and each employee under consideration. Moreover, it has to be decided which workplace attributes should be covered. Either a normal ordinal scale or the

absolute measurement mode of the AHP can be employed for these assessments. Combining the competences and these competence levels yields the employee competence profiles. Moreover, the employees have to assess their preferences regarding the competences and the values of workplace attributes. The employees have to assess how much they prefer using one competence over another employing the relative measurement mode of the AHP.

In the third step, which can take place simultaneously, the workplace requirement profiles have to be constructed. Apart from the determination of the minimum required competence levels, the relative importances w_{ij} of a competence i to a workplace j have to be assessed. The relative measurement mode of the AHP is also employed for this assessment. Furthermore, the actual values of workplace attributes have to be assessed (e.g. the number of work days needed per week to complete the work specific to a workplace). As outlined in section 3, the absolute measurement mode of the AHP may also be appropriate for the assessment of some workplace attributes.

In the following, all inputs needed to solve the goal programming models are listed:

- a_{in} actual level of competence i for employee n
- b_{kj} actual value of workplace attribute k for workplace j
- g_{ij} required level of competence i for workplace j
- h_{kn} preferred value of workplace attribute k for employee n
- I number of competences
- J number of workplaces
- K number of workplace attributes
- N number of employees
- p_{in} preference of employee n regarding competence i
- q_{kn} importance of workplace attribute k to employee n
- u_1 importance of the fulfillment of the required competence levels
- u_2 importance of the fulfillment of the employee's preferences regarding the competences
- u_3 importance of the fulfillment of the employee's preferred values of workplace attributes
- w_{ij} relative importance of competence i to workplace j

5.2 The goal programming models

5.2.1 The preemptive goal programming model. The first part model of the preemptive goal programming model presented below is utilized to establish the set of optimal assignments of employees to workplaces which ensure that the respective workplace's competence level requirements are maximally fulfilled. Each admissible assignment is represented by the decision variable x_{jn} which is set to the value one (zero) if employee n is (not) assigned to workplace j . If more than one assignment set maximally fulfills the competence level requirements, the preferences regarding both the competences and the values of (general) workplace attributes are additionally considered in a second part model. The two types of employee preferences are weighted with their relative importances $u_2 > 0$ and $u_3 > 0$, respectively.

The objective function (4) of the first part model covers the objective of optimally assigning employees to workplaces according to their actual and required competence levels, respectively. This objective is viewed as the first-priority-goal, since the employees have to be able to select the appropriate activities to perform the tasks at the respective workplaces. The objective function only contains the underachievement variables d_{ij}^- as (individually weighted) first-priority-goal variables and not the overachievement variables d_{ij}^+ of the required competence levels, since, in the example considered here, the objective is only to reach or to exceed the required competence levels (lower one-sided goals). Furthermore, the objective function incorporates the relative importance weights w_{ij} of a competence i to a workplace j determined by using the AHP. Expressions such as those in equation (4) prevent a compensation of underachievements and overachievements of competence level requirements. In practice, those expressions play especially a role for the assignment of specialists who should fulfill all weighted competence level requirements as far as possible for specific workplaces (Sure *et al.*, 2000).

Objective function (first part model):

$$\text{MIN } Z_1 = \sum_{i=1}^I \sum_{j=1}^J w_{ij} * d_{ij}^- \quad (4)$$

subject to the constraints:

$$\sum_{n=1}^N a_{in} * x_{jn} + d_{ij}^- - d_{ij}^+ = g_{ij} \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J \quad (5)$$

$$d_{ij}^+, d_{ij}^- \geq 0 \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J \quad (6)$$

$$N = J \vee N > J \longrightarrow \sum_{n=1}^N x_{jn} = 1 \quad \forall j = 1, \dots, J \quad (7a)$$

$$N < J \longrightarrow \sum_{n=1}^N x_{jn} \leq 1 \quad \forall j = 1, \dots, J \quad (7b)$$

$$N = J \vee N < J \longrightarrow \sum_{j=1}^J x_{jn} = 1 \quad \forall n = 1, \dots, N \quad (8a)$$

$$N > J \longrightarrow \sum_{j=1}^J x_{jn} \leq 1 \quad \forall n = 1, \dots, N \quad (8b)$$

$$x_{jn} \in \{0; 1\} \quad \forall j = 1, \dots, J, \quad \forall n = 1, \dots, N \quad (9)$$

$$0 \leq w_{ij} \leq 1 \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J \quad (10a)$$

$$\sum_{i=1}^I w_{ij} = 1 \quad \forall j = 1, \dots, J \quad (10b)$$

The underachievement variables d_{ij}^- and the overachievement variables d_{ij}^+ guarantee that constraint (5) can always be fulfilled. From another point of view, constraint (5) ensures in connection with constraint (6) that the values of the deviational variables d_{ij}^- and d_{ij}^+ are implicitly (model endogenously) determined. The non-negativity constraint

(6) prevents the underachievement variables and the overachievement variables from becoming negative. Constraint (7a) ensures that each workplace receives exactly one employee if the number of employees to be assigned is equal to or greater than the number of workplaces. According to constraint (7b), if there are more workplaces than available employees, every workplace receives at most one employee. Constraint (8a) ensures that each employee is assigned to exactly one workplace, if at least so many employees as workplaces are available. But, if the number of employees exceeds the number of workplaces, constraint (8b) causes that not every employee is assigned to a workplace. Constraint (9) requires all decision variables x_{jn} to be binary (one-zero). Finally, constraint (10a) defines the range of possible values for the AHP importance weights w_{ij} and constraint (10b) normalizes the importance weights w_{ij} to one.

If the first part model above leads to more than one optimal solution, the second part model below considering additionally the second-priority-goals has to be solved. The expression in the first row of the objective function (11) considers the deviations of the relative importances of the competences (for each assigned workplace j) from the employees' preferences regarding the competences P_{in} . This expression contains the underachievement variables d_{in}^- as well as the overachievement variables d_{in}^+ , since the goal is to meet exactly the preferences (two-sided goals). In the second row of the objective function (11), the deviations of actual values b_{kj} (for each assigned workplace j) from preferred values h_{kn} of each workplace attribute k are considered for each employee n . Since the preferred values should be met exactly (two-sided goals), such as hours of work per day, and number of work days in a week, underachievement variables d_{kn}^- and overachievement variables d_{kn}^+ are used once again. Other workplace attributes may be considered as one-sided goals. Some workplace attributes may require that a certain level is reached or exceeded (lower one-sided goals). Examples of these workplace attributes are "operational safety" and "office space". Other workplace attributes may need to be achieved equal to or below a certain level (upper one-sided goals). Examples of such workplace attributes are "air pollution" and "noise pollution". To simplify matters, the objective function (11) does not take into account attributes viewed as one-sided goals, but it can easily be adjusted to do so.

The constraints (5), (6), (7a), (7b), (8a), (8b), and (9) of the first part model dedicated only to first-priority-goals also apply for the second part model considering additionally the second-priority-goals. The constraints (12) and (13) ensure in connection with constraints (14) and (15), respectively, that the values of the deviational variables d_{in}^+ , d_{in}^- , d_{kn}^+ , and d_{kn}^- are implicitly (model endogenously) determined. The non-negativity constraints (14) and (15) prevent the deviational variables d_{in}^+ , d_{in}^- , d_{kn}^+ , and d_{kn}^- from becoming negative. Constraint (16) ensures in the same way that the importance weights u_2 and u_3 do not become negative and that they sum up to one. The constraints (17) and (18) normalize the values of the workplace attributes that are measured on substantially different scales (e.g. "number of work days in a week" and "office space"). These two constraints are not required, if all workplace attributes are assessed utilizing the absolute measurement mode of the AHP. Constraint (19) ensures that the maximal level Z_1^* of weighted fulfillment of all first-priority-goals which is realized by all optimal solutions of the first part model also holds in the second part model. Therefore constraint (19) plays the role of an integrity condition for consistently linking the second to the first part model of the same real assignment problem.

Objective function (second part model):

$$\text{MIN} \left[\begin{array}{l} u_2 * \left(\sum_{i=1}^I \sum_{n=1}^N d_{in}^- + d_{in}^+ \right) \\ + u_3 * \left(\sum_{k=1}^K \sum_{n=1}^N q_{kn} * (d_{kn}^- + d_{kn}^+) \right) \end{array} \right] \quad (11)$$

subject to the constraints:

(5), (6), (7a), (7b), (8a), (8b) and (9)

$$\sum_{j=1}^J w_{ij} * x_{jn} + d_{in}^- - d_{in}^+ = p_{in} \quad \forall i = 1, \dots, I, \quad \forall n = 1, \dots, N \quad (12)$$

$$\sum_{j=1}^J b_{kjm}^N * x_{jn} + d_{kn}^- - d_{kn}^+ = h_{kn}^N \quad \forall k = 1, \dots, K, \quad \forall n = 1, \dots, N \quad (13)$$

$$d_{in}^+, d_{in}^- \geq 0 \quad \forall i = 1, \dots, I, \quad \forall n = 1, \dots, N \quad (14)$$

$$d_{kn}^+, d_{kn}^- \geq 0 \quad \forall k = 1, \dots, K, \quad \forall n = 1, \dots, N \quad (15)$$

$$u_2, u_3 \geq 0 \quad \wedge \quad u_2 + u_3 = 1 \quad (16)$$

$$b_{kjm}^N = \frac{b_{kj}}{h_{kn}} \quad \forall k = 1, \dots, K, \quad \forall j = 1, \dots, J, \quad \forall n = 1, \dots, N \quad (17)$$

$$h_{kn}^N = \frac{h_{kn}}{h_{kn}} = 1 \quad \forall k = 1, \dots, K, \quad \forall n = 1, \dots, N \quad (18)$$

$$Z_1^* = \sum_{i=1}^I \sum_{j=1}^J w_{ij} * d_{ij}^- \quad (19)$$

5.2.2 The non-preemptive goal programming model. The non-preemptive goal programming model presented below is capable of considering all three objectives simultaneously. In contrast to the preemptive goal programming model, the following non-preemptive model allows compensation effects between the three objectives.

The objective function (20) seeks the optimal solutions of the assignment model. Each row of the objective function (20) represents one of the three objectives. As in the preemptive model, the first objective refers to lower one-sided goals, while the second and the third objectives refer to two-sided goals. The first row covers the assignment of the employees to workplaces according to the weighted (u_1) fit of weighted (w_{ij}) actual and required levels of competence for employees versus workplaces, respectively. The expression in the second row of the objective function (20) considers the weighted (u_2) fit of the employee preferences regarding the competences and the relative importances of the competences to the workplaces, while the expression in the third row covers the weighted (u_3) fit of weighted (q_{kn}) preferred versus actual values of workplace attributes. It is possible that there are several different assignment sets meeting the competence level requirements and preferences in the same optimal way, i.e. with the same maximal value of the objective function (20). Especially compensation effects between the three objectives can lead to several optimal solutions of the assignment model.

$$\text{MIN} \left[\begin{array}{l} u_1 * \left(\sum_{i=1}^I \sum_{j=1}^J w_{ij} * d_{ij}^- \right) \\ + u_2 * \left(\sum_{i=1}^I \sum_{n=1}^N d_{in}^- + d_{in}^+ \right) \\ + u_3 * \left(\sum_{k=1}^K \sum_{n=1}^N q_{kn} * (d_{kn}^- + d_{kn}^+) \right) \end{array} \right] \quad (20)$$

subject to the constraints:

$$(5), (6), (7a), (7b), (8a), (8b), (9), (10a), (10b), (12), (13), (14), (15), (17) \text{ and } (18) \\ u_1 \geq 0, u_2 \geq 0, u_3 \geq 0 \quad \wedge \quad u_1 + u_2 + u_3 = 1 \quad (21)$$

The constraints (5) to (10b), (12) to (15), (17), and (18) from the preemptive model also apply for the non-preemptive model, while constraint (21) is analogous to constraint (16).

6. Illustrative application

The illustrative application is taken from a personnel services company called Affirmu Outsourcing Ltd. The core business of Affirmu is to offer personnel services for companies in the insurance business.

Usually, the Affirmu employees are working in project teams in the customers' offices. The customers want Affirmu to place competent staff at their disposal to overcome capacity restraints, since they do not want to hire additional staff. Mostly, the Affirmu employees have to work with a branch solution of a popular enterprise Resource Planning System (ERP-System). In a project team working for a key customer three employees need to be replaced, since two of them are going on vacation and the customer is dissatisfied with the performance of the third one. Table I shows a list of competences relevant for the customer.

In cooperation with the customer the responsible Affirmu project manager has compiled the list with the levels of competence in Table II, which are at least required at the three vacant workplaces.

The absolute measurement mode of AHP has been employed to judge the preference for each competence level. As can be seen from Table III, there is a strong preference for

Competence number	Competence
1	Knowledge of life insurance products
2	Knowledge of health insurance products
3	Knowledge of personal accident insurance products
4	Knowledge of insurance law
5	Knowledge of customizing the ERP-systems
6	Knowledge of the ERP-system
7	Knowledge of the customer relationship management (CRM)-system
8	Programming knowledge
9	Network technology knowledge
10	English language knowledge
11	Spanish language knowledge

Table I.
List of relevant competences

Table II.
Required levels
of competence

Competence number	1 (CRM department)	Workplace number	
		2 (Accounts department)	3 (IT department)
1	Expert	Expert	Average
2	Expert	Expert	Average
3	Expert	Expert	Average
4	Above average	Expert	Expert
5	Above average	Dilettante	Expert
6	Average	Expert	Expert
7	Expert	Average	Expert
8	Dilettante	Dilettante	Expert
9	Dilettante	Dilettante	Above average
10	Above average	Above average	Dilettante
11	Below average	Below average	Dilettante

Table III.
Preferences for
competence levels

Competence level	Pair wise comparison matrix	Normalized eigenvector
Expert	$A = \begin{pmatrix} 1 & 2 & 6 & 8 & 9 \\ 1/2 & 1 & 3 & 5 & 9 \\ 1/6 & 1/3 & 1 & 2 & 3 \\ 1/8 & 1/5 & 1/2 & 1 & 2 \\ 1/9 & 1/9 & 1/3 & 1/2 & 1 \end{pmatrix}$	$v_{\text{norm}} = \begin{pmatrix} 0.502 \\ 0.296 \\ 0.103 \\ 0.061 \\ 0.038 \end{pmatrix}$
Above average		
Average		
Below average		
Dilettante		

the competence levels “expert” and “above average” in comparison to the other ones, since the customer wants to ensure high quality services. For the same reason the preemptive goal programming model has been chosen.

Additionally, the customer has to assess the relative importance w_{ij} of each competence in Table I to each workplace. Hence, the customer has to fill out a pair wise comparison matrix for each workplace. The normalized eigenvectors derived from these matrices are shown in Table IV.

At this point, the customer has provided all data required to solve the first part model. However, the Affirmu project manager has to find out what employees are available and what their competence levels are. Affirmu has six employees not

Table IV.
Relative importance
of a competence to
a workplace

Competence number	1 (CRM department)	Workplace number	
		2 (Accounts department)	3 (IT department)
1	0.142	0.118	0.052
2	0.142	0.121	0.052
3	0.142	0.127	0.052
4	0.136	0.224	0.052
5	0.014	0.014	0.144
6	0.068	0.063	0.139
7	0.142	0.127	0.139
8	0.014	0.014	0.141
9	0.014	0.014	0.144
10	0.124	0.115	0.062
11	0.062	0.063	0.023

scheduled to work at the requested time. So the project manager compiled the competence list in Table V.

At this instant, Affirmu has all data to solve the first part model. The solution of this model delivers two alternative optimal assignment sets with the same maximal objective function value. Employee 1 is assigned to workplace 3 in both of these assignment sets. But in the first one employee 4 is assigned to workplace 1 and employee 6 to workplace 2, while in the second one employee 4 is placed to workplace 2 and employee 6 to workplace 1. The reason is that employees 4 and 6 may have similar competence profiles. All other employees are not assigned to any workplace, since only three employees are needed to fulfill the requirements of the customer. In order to select one of these assignment sets, the second part model has to be solved.

Therefore, each of the six employees has to evaluate his preferences regarding the competences by filling out a pair wise comparison matrix of dimension 11. Then, a normalized eigenvector is calculated for each pair wise comparison matrix. Those eigenvectors are given in Table VI.

The information concerning the workplace attributes also has to be gathered. In this illustrative application the two workplace attributes “number of work days in a week” and “number of work hours in a week” are considered. In Table VII the results q_{kn} of the evaluation of the workplace attribute importances are given.

The employees have to also specify their preferred values h_{kn} of the workplace attributes. Those values are given in Table VIII.

In contrast, the actual values b_{kj} of the workplace attributes have to be gathered. These values are given in Table IX for the three workplaces.

Competence number	Employee number					
	1	2	3	4	5	6
1	Above average	Dilettante	Dilettante	Below average	Below average	Below average
2	Above average	Below average	Above average	Above average	Average	Above average
3	Above average	Average	Below average	Above average	Above average	Above average
4	Average	Below average	Below average	Expert	Dilettante	Expert
5	Above average	Dilettante	Dilettante	Dilettante	Dilettante	Dilettante
6	Expert	Below average	Below average	Below average	Dilettante	Below average
7	Expert	Below average	Below average	Average	Dilettante	Average
8	Above average	Dilettante	Dilettante	Dilettante	Dilettante	Dilettante
9	Above average	Dilettante	Dilettante	Below average	Dilettante	Below average
10	Above average	Below average	Below average	Above average	Average	Above average
11	Dilettante	Dilettante	Dilettante	Below average	Dilettante	Below average

Table V.
Actual levels of competence of available employees

Table VI.
Employee preferences
regarding the
competences

Competence number	Employee number					
	1	2	3	4	5	6
1	0.018	0.168	0.040	0.166	0.054	0.038
2	0.018	0.213	0.158	0.166	0.170	0.037
3	0.018	0.213	0.148	0.166	0.170	0.037
4	0.044	0.211	0.198	0.166	0.288	0.115
5	0.147	0.018	0.038	0.015	0.031	0.117
6	0.142	0.025	0.038	0.040	0.063	0.209
7	0.142	0.025	0.038	0.065	0.063	0.125
8	0.163	0.019	0.038	0.014	0.034	0.121
9	0.143	0.023	0.038	0.014	0.047	0.121
10	0.127	0.043	0.165	0.140	0.056	0.049
11	0.038	0.042	0.101	0.048	0.024	0.031

Table VII.
Importances of the
workplace attributes to
the employees

Employee number	1	2	3	4	5	6
Number of work days in a week	0.50	0.80	0.80	0.75	0.50	0.80
Number of work hours in a week	0.50	0.20	0.20	0.25	0.50	0.20

Table VIII.
Employee preferences
regarding the general
conditions of
the workplace

Employee number	1	2	3	4	5	6
Number of work days in a week	5	3	5	5	4	3
Number of work hours in a week	40.00	24.00	40.00	40.00	34.00	25.50

Table IX.
General conditions of
the workplaces

Workplace number	1	2	3
Number of work days in a week	5	3	5
Number of work hours in a week	40.00	24.00	40.00

The employees' preferences regarding the competences and the general conditions of the workplace are considered to be equally important, since both relate to the working time, so that u_2 and u_3 are set to 0.5. At this point, the second part model can be solved keeping the optimal objective function value Z_1^* unchanged. This second part model has only one optimal solution. According to the solution of this second part model it is optimal to assign employee 4 to workplace 1 and employee 6 to workplace 2.

7. Conclusion

Two formal models on the assignment of employees to workplaces have been presented in this paper. The optimal solution of a model delivers at least one assignment set minimizing the sum of the weighted discrepancies. These discrepancies are firstly caused by the weighted deviations between competence levels required for a workplace and the actual competence levels of the employees, secondly caused by the deviations between the importances of competences to a workplace and the employees' preferences regarding the competences, as well as thirdly caused by the weighted

deviations between the actual workplace attributes and the employees' preferred values of the workplace attributes.

The goal programming models can be solved using a commercially available software package for solving optimization problems such as Lingo (Lindo Systems Inc., 2006). Moreover, in order to facilitate the assessments, professional AHP-software like Expert Choice, (Expert Choice Inc., 2006) can be utilized.

However, the practical application of the models has some shortcomings. An apparent weakness of the presented models is that they rely on a significant amount of input data, as can be seen in the sample application in the previous section. Another obvious problem could be that the input data is not updated regularly. Hence, for example, the documentation of the competence profiles and the preferences of the employees might be out of date or incomplete. This situation may cause misleading assignment sets. It is to be hoped that some of the new approaches, mentioned in section 1, for the computer-based automatic inquiry of competences are going to help to overcome these weaknesses.

Some of the input data may be fuzzy. For example, a decision maker may be uncertain about the required competence level for a specific workplace. For that case, enhanced goal programming models have been proposed using the concept of fuzzy sets (Martel and Aouni, 1998; Pal and Moitra, 2003). Therefore, future research should be directed towards developing fuzzy goal programming models for the competence and preference-based workplace assignment. However, fuzzy sets are too much for many people to handle. So the simplicity of the presented models may be their strength in practice.

Another problem may occur if an employee to be assigned has irreconcilable differences with another employee assigned to a workplace in the vicinity of the first employee's workplace, so that the enforced cooperation demotivates both employees and thus outweighs the efficiency gains of the workplace assignment delivered by the goal programming models. Future models could be improved by considering employee preferences regarding potential colleagues. Moreover, the employee to be assigned may be content with her or his present workplace and may thus dislike an assignment to another workplace. One way to deal with this problem is to ask the employees, before applying one of the goal programming models, whether they agree with an assignment to another workplace. In that case, only the employees agreeing with the assignment to another workplace may be considered in the goal programming models.

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