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Decision Support

A mathematical model proposal for cost-effective course planning in large hierarchical organizations

Levent Karamalak [a,*], Ihsan Sabuncuoglu [b], Altan Ozkil [c]

[a] Turkish Land Forces, Erzincan, Turkey
[b] Rector of Abdullah Gul University, Kayseri, Turkey
[c] Department of Industrial Engineering, Atılım University, Ankara, Turkey

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ABSTRACT

Hierarchical organizations, especially in government agencies, are known by their pyramidal structures and continuous training needs resulting from promotions and/or assignments. Using scientific and rational methods in the job analysis/description, recruitment/selection, assignment, performance appraisal and career planning functions of human resource management (HRM) process decreases training costs. In this study, we develop a new chain of methodologies (the cost-effective course planning model (CECPM)) to decrease training costs and increase the level of specialization. This methodology is implemented in the following steps of the HRM process: (1) the job analysis/description step, where our Mission Description Matrix defines in measurable units the amount of training needed for an employee assigned to a position, (2) the career matrix step, where the minimum training costs for an employee's career path are determined using our network-flow model and (3) the assignment step, where we propose a decision support system composed of an analytical hierarchy process, linear programming and Pareto optimality analysis. The results indicate that our proposed system ensures minimum training needs while satisfying person-to-position compatibility and personnel's preferences.

1. Introduction

With many personnel in different categories and levels, large hierarchical organizations engage in bottom-up assignments due to promotions and horizontal assignments. In this process, to build on the knowledge and experience gained in lower levels, supplemental training is inevitably necessary and training costs are a major aspect of the organization's budget. Hence, measures should be taken to lower training costs while still fulfilling training requirements.

Course planning is carried out within the training and development function of HRM. However, as this function should be implemented compatibly with the HRM sub-functions of job analysis, performance management, career management, and assignments an integrated approach to course planning is best.

To determine a training need, one compares personnel qualifications with position competencies. Choosing personnel with the best skills for the position reduces the amount of training needed. Often, however, other factors such as period of service, promotion needs, specialization, job diversity and a large number of personnel (several ten thousands) must be considered. Career planning for personnel increases motivation and the quality of an organization. It should also take into account specialization and minimum-cost training. For these reasons, career management and course planning should be simultaneously considered in HRM.

Job analysis/description and training requirements are also strongly connected. Job analysis/description processes measure the relationships between different positions and can thus determine the amount of training a person needs.

Fig. 1 shows a frequently used course planning activity in hierarchical organizations. Each factor resulting in a training need is considered as an input. Training needs are then evaluated in coordination and cooperation with internal and external training centers and an output "course plan" is constructed. In such an activity, the only attempt at decreasing training costs takes place in the process stage. Once the plan is determined, the planner may decide to organize a course at external course centers instead of internal course centers or may consider whether to plan a course for a group of personnel under a certain number.

Significant reductions in training costs can be achieved by decreasing training needs resulted from assignments. The traditional course planning activity assumes that course planning is

* Corresponding author. Address: Aslanli district, Demirkent Loj., No.: C1/8, Erzincan, Turkey. Tel.: +90 4462235830x4101.

E-mail address: leventkaramalak@yahoo.com (L. Karamalak).

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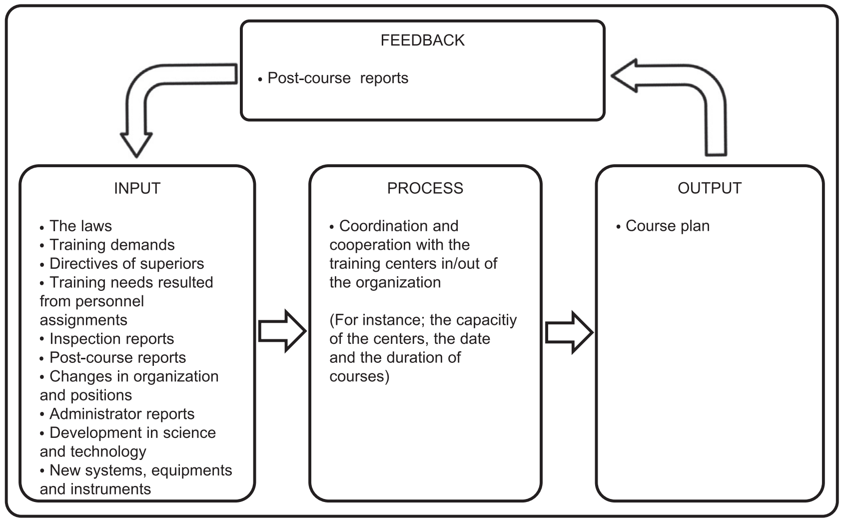

Fig. 1. Traditional course planning in organizations.

independent from the job analysis/description, career planning and assignment functions of HRM. Operations related to these functions are conducted according to their own methodologies; in general no measure is taken to reduce training costs. Problem areas in traditional course planning include excessive courses, long course periods, large number of personnel out of office, overloaded training centers, high costs and insufficient specialization.

The aim of this study is to set forth a chain of methodologies (our cost-effective course planning model (CECPM)) for HRM functions that re-forms training needs to decrease training costs. Basically our CECPM assigns the best personnel (satisfying all assignment criteria) who would need the least training (depending on her/his past experiences) to a position. Thus CECPM intends to guarantee a minimization of training needs just when they are on the verge of occurrence. However achieving minimum training needs may not guarantee minimum training cost. Organizations may need training as a consequence of organizational and performance analyses. On the other hand, a training need turns into cost only when the organization tends to meet this need with a course. The duration, location, method, number of attendees and instructors of the courses affect the cost. Customizing such parameters is a major concern in minimizing the training costs. Although our CECPM or any other study succeeds to minimize the training needs, the cost of the courses may not be optimal depending on the parameter settings. Nevertheless one should assume that minimum amount of training need means less training i.e. lower cost for the same course planning parameter settings. With many personnel in different categories and levels, large hierarchical organizations engage in bottom-up assignments due to promotions and horizontal assignments. When designing courses for newly assigned personnel, the only controllable part in terms of assignment is job analysis-based-trainings. Job analysis-based-trainings also occupy the greatest part in course design and planning process. Therefore we have focused on decreasing job analysis-based-training needs in our study.

The primary objective of our model is to ensure that, according to a workflow, the output of one sub-model is the input of the next sub-model (see Fig. 2). In reality, there is no such order between the functions of HRM, but for the purpose of achieving low-cost training we place HRM functions into this workflow. The steps of our CECPM are listed below:

- Develop a scenario resembling hierarchical organizations.
- Determine the best methodology for each HRM function.
- Implement the methodology into the scenario.
- Present the comparative results.

In Section 2, a brief survey of previous studies is given. Section 3 introduces a scenario for analysis. Section 4 suggests methodologies and/or mathematical models that can be used for the job analysis/description, career planning and assignment functions of HRM to develop low-cost course plans. Section 5 presents the results, and Section 6 concludes the paper.

2. Literature review

The main idea of CECPM is to ensure minimum training needs for cost-effective course plans by satisfying both person-to-position compatibility and personnel preferences. Within this scope, literature embodies several studies focused on assigning people to jobs in some optimal sense.

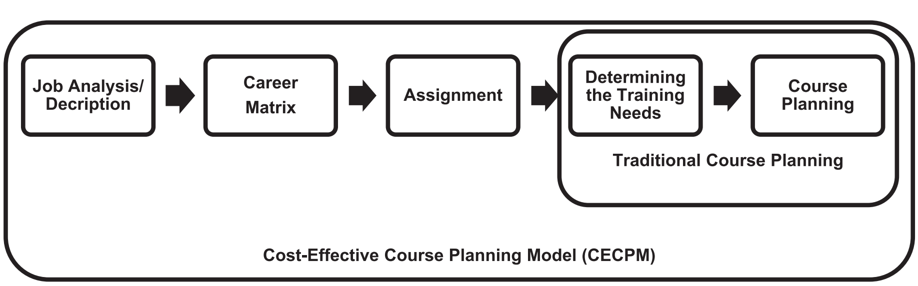

Fig. 2. Cost-Effective Course Planning Model (CECPM).

Jaturanonda and Nanthavanij (2005) introduce two quantitative person-to-position compatibilities to represent the degree of compatibility between a person and a position. They are: (1) competency-based person-to-position compatibility (when the compatibility measure is based on the competency) and (2) preference based person-to-position compatibility (when the assignment is considered according to the position preference of employees). Jaturanonda and Nanthavanij (2011) then discuss an analytic-based decision analysis tool called Employee-Job Assignment System (EJAS) for solving the person-to-position assignment problem. The EJAS is intended to determine a person-to-position assignment solution that optimizes the employees' work efficiency and job satisfaction. Considering two quantitative person-to-position compatibility criteria and depending on the decision-maker's selection, the EJAS determines a solution that maximizes the chosen person-to-position compatibility. Additionally, it generates several near-optimal solutions to assist the decision-maker in selecting a suitable person-to-position assignment solution.

Armacost and Lowe (2005) report on a linear programming (LP) assignment model for United States Air Force Academy graduates. Their algorithm allows measuring and balancing cadets' class standing, Air Force career field requirements, and cadets' career field preferences in order to assign each cadet to a career field in the Air Force. Their computational experiments show the superiority of their method over previous classification approaches. Their method yields more than a 10% increase in the number of cadets assigned to their top career field choice and almost a 100% reduction in the number of cadets not receiving any of their career field choices.

Holder (2005) also proposes a model designed to aid in optimizing the process of assigning sailors to jobs. This procedure attempts to achieve an increased level of sailor satisfaction by providing a list of possible jobs from which a sailor may choose. His study demonstrates that the optimal partition from an interior-point algorithm is particularly useful when designing the job lists.

Peters and Zelewski (2007) seek to develop a model for the assignment of employees to workplaces. In their study two goal programming models are introduced with inputs and valuations using the analytic hierarchy process (AHP). 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.

Korkmaz, Gökçen, and Çetinyokuş (2008) propose a decision support system programmed to generate positions' preferences from position requirement profiles and personnel competence profiles by using AHP and matches personnel to positions by using a two-sided matching.

Bhargava and Snoap (2003) propose improvements to the existing United States Marine Corps decision processes and information systems for recruit distribution. The proposed system, recruit distribution decision support system (RDdss), provides intuitive navigation through a hierarchy of switchboards and promotes data integrity by eliminating manual data entry for data already available in the system. It incorporates four objective measures for understanding the quality of proposed distributions and allows the user to generate and compare multiple solutions based on the trade-off between these objectives.

The problem we consider differs from these previous studies in two key respects. First, we are not considering only one-to-one assignments of persons to positions; rather, we propose a methodology to embed the effect of training costs in the assignment process by exploiting the job analysis/description and career matrix steps of CECPM. In hierarchical organizations, most of which are government agencies, more job rotations occur compared to private companies (Jaturanonda, Nanthavanij, & Chongphaisal, 2006). Job rotation demands in service training and education and hence requires an increase in direct training expenses and time spent for learning (Campion, Cheraskin, & Stevens, 1994). Training cost is reported to be the most predominant cost associated with job rotation (Jaturanonda et al., 2006). In this regard we believe that not only person-to-position compatibility and personnel preferences but also training cost is an important issue in assignment process. Therefore, CECPM is targeted to lessen training costs which are mostly caused by job rotations. Second, in the assignment step of CECPM we propose a decision support system composed of AHP, LP and Pareto optimality analysis. Our proposed system provides alternative optimal assignments varying according to the pairs of weights allocated to person-to-position compatibility and personnel preferences, and it ensures minimum training needs while satisfying person-to-position compatibility and personnel's preferences. We also present a rational way to choose the most appropriate pair of weights leading to the most efficient solution by utilizing Pareto optimality analysis.

3. The scenario

Suppose that a hypothetical hierarchical organization (for ease of understanding we employ a small military organization) consists of positions, levels and inter-position relationships shown in Fig. 3. Starting from graduation from a military academy to the upper levels of the organization G_i ($i = 1,2,\ldots,24$) stands for positions. The characteristics of the organization are as follows:

- After graduation from the academy (G_0), an officer may belong to one of two branches: Branch I or branch T.
- Between graduation and their first assignments, officers are subjected to basic training (G_T and G_I).
- Career paths are different for branch I and T. There are positions unique to each branch (i.e. those for branch T are G_1, G_2, G_3, G_4, G_5, G_6, G_7) as well as joint positions, to which officers in either branch can be assigned (G_8, G_9, G_{10}, G_{11}, G_{12}, G_{13}, G_{14}).
- Positions are clustered in a four-level order. An officer must be a Lieutenant–First Lieutenant for the first-level positions, a Captain for the second-level positions, a Major-Lieutenant Colonel for the third-level positions and a Colonel for the fourth-level positions. To be promoted to upper-level positions, one must have served in one of the preceding-level positions and have the appropriate rank for the new position (for example a branch T officer must have served in one of the positions G_1, G_2, G_8, G_9 and must be a Captain to serve in G_{10}).
- After the first-level positions, officers from both branches can be shifted to branch S after a selection process and attending branch S training (G_S). Branch S officers are assigned according to their own career paths.
- The total numbers of competencies needed to execute the requirements for each position are shown in Table 1.
- Training is a necessity after being assigned to a new position.
- Officers' preferences should be taken into consideration in assignment processes.
- According to the scenario, there are 105 officers with different qualifications waiting to be assigned to a higher-level position. The number of officers to be assigned and the number of vacant positions are equal to each other. As an example, in Table 2 we present the qualifications of 16 officers currently in first-level positions. In Fig. 3, the number of officers waiting to be assigned from any duty and their branches are indicated under the box of that duty; the number of empty positions belonging to any duty is indicated above the box of that duty.

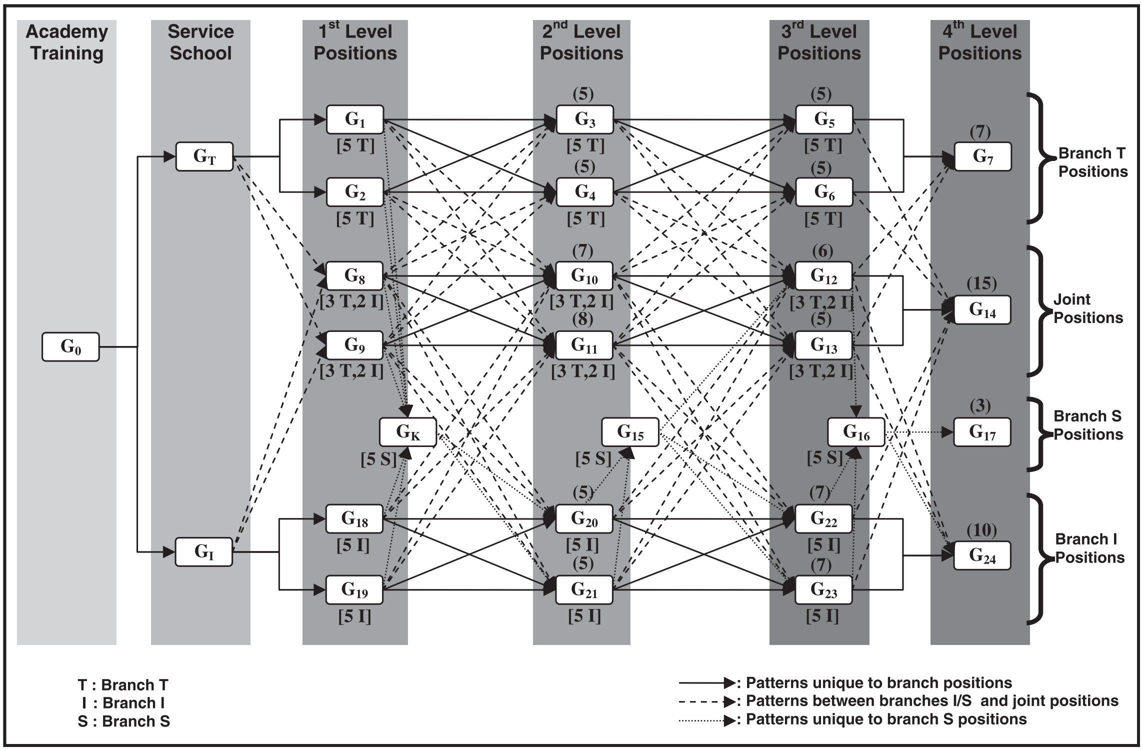

Fig. 3. Network of patterns for branch I and T.

Table 1
Chart of positions.

Branch	T								I								Joint positions							S			
Code	G_T	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_I	G_{18}	G_{19}	G_{20}	G_{21}	G_{22}	G_{23}	G_{24}	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_S	G_{15}	G_{16}	G_{17}
Number of competencies needed	0	52	52	52	60	26	55	59	0	47	42	39	47	49	56	32	35	48	45	23	33	63	15	74	38	40	23

Given the characteristics of military organizations, such as strict rules, pyramidal structure, precisely defined duties, ranks and chains of command, and an organizational structure based on specialties, we feel our scenario is a good representation of actual organizations and that the results derived from our analysis can be used by hierarchical organizations.

4. Model and analyses

4.1. Job analysis/description

Job analysis/description is the first step of our CECPM. The method used to do this should be compatible with methods used in the subsequent steps. Considering job analysis/description templates only from the perspective of the HRM function, those presented in the literature may be adequate to answer the question of which job will be done by whom and how? However, for the goal of low-cost training, a job analysis/description form should assess the following factors:

- Competence differences between positions.
- Training deficits as a result of assignments.
- How career paths affect training costs.
- Placing employees in positions with the least amount of skill deficit.

Prien, Goodstein, Goodstein, and Gamble (2009) propose four basic steps to prepare job description guides: (1) determine the tasks done in each position, (2) determine the competencies of information, skills and talent necessary to perform the tasks, (3) determine workplace specifications affecting job performance, and (4) set job performance levels.

Competency definitions should be expressed with identical codes and in matrix form so that joint competencies can be detected (positions with different responsibilities may have common competencies). To model such a situation, positions in our scenario are assumed to have some common competencies. Part of our scenario's job description matrix is shown in Table 3. The value "1" in this matrix shows positions needing the related competency in the left column. The value also applies to the amount of training necessary to achieve the competency for the corresponding position. For simplicity, the amount of training needed for any competency for any position is assumed to be "1".

4.2. Career matrix

Career plans should satisfy employees' goals as well as the organization's objectives. In negotiating those two processes (which can often contradict each other) career plans should ensure that employee promotions support specialization and decrease training expenditures. Determining the next position for a personnel, who has assumedly accomplished a previous sequence of duties in the

Table 2
Qualification scores of personnel on branch T (1st level positions).

Criteria		Branch T															
		Per.1	Per.2	Per.3	Per.4	Per.5	Per.6	Per.7	Per.8	Per.9	Per.10	Per.11	Per.12	Per.13	Per.14	Per.15	Per.16
Education	High school	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	University	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Master	1	0	1	1	1	0	0	0	1	0	0	1	0	0	0	1
	Doctorate	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Courses	Course A	1	1	0	0	1	1	1	1	1	0	1	0	1	1	1	0
	Course B	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	1
	Course C	0	1	1	1	0	1	0	0	0	0	1	1	0	0	1	1
	Course D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Speciality	T	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	S	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rank	Lieutenant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1st Lieutenant	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Captain	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Major	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Lt. Colonel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Colonel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Previous duty	G1	1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1
	G2	0	0	1	0	0	0	0	0	1	1	1	0	0	0	1	0
	G8	0	0	0	1	0	0	0	0	0	0	0	1	0	1	0	0
	G9	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0
	GS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Experience	Months of service	0.25	0.28	0.25	0.31	0.28	0.25	0.28	0.31	0.31	0.25	0.28	0.25	0.28	0.31	0.25	0.31
	Service score	0.56	0.51	0.47	0.55	0.56	0.52	0.55	0.59	0.52	0.51	0.55	0.56	0.51	0.47	0.58	0.45
Evaluation	Appraisal score	0.95	0.97	0.91	0.99	0.85	1	0.98	1	1	0.94	0.71	0.96	1	0.99	0.88	0.92
	Awards score	0.34	0.41	0.32	0.45	0.32	0.48	0.42	0.43	0.45	0.34	0.28	0.45	0.49	0.5	0.36	0.35
	Penalty score	0	0	0	0	-0.1	0	0	0	0	0	-0.25	0	0	0	0	0
Foreign language	Language A	0.82	0.62	0.74	0.89	0.62	0.75	0.95	0.86	0.56	0.62	0.5	0.78	0.95	0.6	0.6	0.8
	Mission abroad	0	0	0	1	0	1	1	0	0	0	0	0	1	0	0	0
Marital status	Married	1	0	1	1	1	1	0	0	0	1	0	1	1	1	1	1
	Single	0	1	0	0	0	0	1	1	1	0	1	0	0	0	0	0
Health and physical status	Physical test Sc.	0.8	0.9	0.85	0.85	0.88	0.9	0.98	0.96	0.96	0.78	0.81	0.99	0.91	0.88	0.94	0.82
	Minor problems	1	0	1	1	0	0	0	0	0	1	0	0	0	0	1	1
	No problem	0	1	0	0	0	1	1	1	1	0	1	1	1	1	0	0
	Height	1.75	1.81	1.79	1.65	1.63	1.71	1.82	1.77	1.63	1.75	1.69	1.79	1.85	1.7	1.78	1.77
Gender	Male	1	1	1	0	0	1	1	1	0	1	1	1	1	0	1	1
	female	0	0	0	1	1	0	0	0	1	0	0	0	0	1	0	0
Total		16.47	14.5	14.33	16.69	14.04	15.61	15.98	13.92	14.43	12.19	14.57	14.78	14.99	13.45	14.39	15.42

Table 3
Part of job description matrix.

Competencies	Positions																							
	Branch T							Branch I							Joint positions							Branch S		
	G_1	G_2	G_3	G_4	G_5	G_6	G_7	G_{18}	G_{19}	G_{20}	G_{21}	G_{22}	G_{23}	G_{24}	G_8	G_9	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{15}	G_{16}	G_{17}
c1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1			1				
c2	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1		1		
c3	1	1	1	1		1	1			1	1	1	1	1	1	1	1		1					
c4	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1		1	1		1	1	1
c5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
...																								

Table 4
Transition costs matrix.

POSITIONS			Branch T								Branch I								Joint Positions							Branch S			
			GU	G1	G2	G3	G4	G5	G6	G7	GP	G18	G19	G20	G21	G22	G23	G24	G8	G9	G10	G11	G12	G13	G14	GK	G15	G16	G17
Total Competencies Needed			0	52	52	52	60	26	55	59	0	47	42	39	47	49	56	32	35	48	45	23	33	63	15	74	38	40	23
Barnch T	GU	0	0	2	2	M	M	M	M	M	M	M	M	M	M	M	M	M	3	2	M	M	M	M	M	M	M	M	M
	G1	52	M	0	M	6	18	M	M	M	M	M	M	M	M	M	M	M	M	M	10	14	M	M	M	74	M	M	M
	G2	52	M	M	0	6	18	M	M	M	M	M	M	M	M	M	M	M	M	M	10	14	M	M	M	74	M	M	M
	G3	52	M	M	M	0	M	18	3	M	M	M	M	M	M	M	M	M	M	M	M	M	9	26	M	M	M	M	M
	G4	60	M	M	M	M	0	18	8	M	M	M	M	M	M	M	M	M	M	M	M	M	9	25	M	M	M	M	M
	G5	26	M	M	M	M	M	0	M	51	M	M	M	M	M	M	M	M	M	M	M	M	M	M	9	M	M	M	M
	G6	55	M	M	M	M	M	M	0	19	M	M	M	M	M	M	M	M	M	M	M	M	M	M	10	M	M	M	M
	G7	59	M	M	M	M	M	M	M	0	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Branch I	GP	0	M	M	M	M	M	M	M	M	0	2	2	M	M	M	M	M	2	2	M	M	M	M	M	M	M	M	M
	G18	47	M	M	M	M	M	M	M	M	M	0	M	10	19	M	M	M	M	M	17	16	M	M	M	74	M	M	M
	G19	42	M	M	M	M	M	M	M	M	M	M	0	8	6	M	M	M	M	M	20	13	M	M	M	74	M	M	M
	G20	39	M	M	M	M	M	M	M	M	M	M	M	0	M	17	25	M	M	M	M	M	13	34	M	M	24	M	M
	G21	47	M	M	M	M	M	M	M	M	M	M	M	M	0	16	23	M	M	M	M	M	12	32	M	M	21	M	M
	G22	49	M	M	M	M	M	M	M	M	M	M	M	M	M	0	M	9	M	M	M	M	M	M	10	M	M	17	M
	G23	56	M	M	M	M	M	M	M	M	M	M	M	M	M	M	0	9	M	M	M	M	M	M	10	M	M	16	M
	G24	32	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	0	M	M	M	M	M	M	M	M	M	M	M
Joint Positions	G8	35	M	M	M	21	29	M	M	M	M	M	M	12	18	M	M	M	0	M	14	16	M	M	M	74	M	M	M
	G9	48	M	M	M	22	30	M	M	M	M	M	M	10	17	M	M	M	M	0	15	15	M	M	M	74	M	M	M
	G10	45	M	M	M	M	M	18	18	M	M	M	M	M	M	15	21	M	M	M	0	M	8	31	M	M	M	M	M
	G11	23	M	M	M	M	M	20	46	M	M	M	M	M	M	40	47	M	M	M	M	0	24	54	M	M	M	M	M
	G12	33	M	M	M	M	M	M	M	36	M	M	M	M	M	M	M	16	M	M	M	M	0	M	11	M	M	23	M
	G13	63	M	M	M	M	M	M	M	26	M	M	M	M	M	M	M	11	M	M	M	M	M	0	10	M	M	M	M
	G14	15	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	0	M	M	M	M
Branch S	GK	74	M	M	M	M	M	M	M	M	M	M	M	10	12	M	M	M	M	M	M	M	M	M	M	M	M	M	M
	G15	38	M	M	M	M	M	M	M	M	M	M	M	M	M	30	36	M	M	M	M	M	17	M	M	M	0	M	M
	G16	40	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	14	M	M	M	M	M	M	M	M	M	0	7
	G17	23	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	0	M	M

organization, should not be left to the whims of a manager or HRM specialist.

The main aim in the career matrix step of our CECPM is to determine the predecessor position(s) with regards to minimum training costs for each position using our network-flow model. The transition costs matrix (Table 4), which is the output of the CECPM's job analysis/description step, is now the input of the career matrix step. The transition costs matrix calculates the quantity of training needed by an employee assigned to a new position. This matrix also includes the costs of all possible inter-positional transitions in the scenario, calculated from the information in Table 3. For example, the training cost of transition G_1–G_3 is 6 units, and G_1–G_4 is 18 units. These values were calculated by extracting the number of competencies in the column of the related position (having value "1" in the column of related position) from the number of competencies required for the new position. In Table 4, "M" is used for the costs of transitions that are impossible according to the scenario.

Now, if we assume the positions in the scenario (G_i, $i = 0, 1, \ldots, 24$) are nodes, the possible transitions between the positions are edges, and the values in Table 4 are distances between the nodes, then the career planning step of our CECPM is nothing but a shortest-path network-flow problem. If we apply this approach to the scenario in Fig. 3, the result is a single-source directed graph with nonnegative weights, as shown in Fig. 4.

The goal of shortest-path network-flow problems is to find a path between two nodes on a graph where the sum of the weights of its constituent edges is minimized. There are several algorithms in the literature that can solve shortest-path problems on a directed graph with nonnegative weights, such as Dijkstra's algorithm (see Hamdy, 2007). For a given source node on the graph, the algorithm finds the path with lowest cost (i.e. the shortest path) between that node and every other node, and runs in $O(|n|^2)$, producing a shortest-path tree. Additional algorithms and associated evaluations may be found in (Cherkassky et al., 1993). The steps of Dijkstra's algorithm are shown below:

Step 0: Label the source node (node 1) with the permanent label $[0, -]$. Set $i = 1$.
Step i:
(a) Compute the temporary labels $[u_i + d_{ij}, i]$ for each node j that can be reached from node i, provided j is not permanently labeled. If node j is already labeled with $[u_j, k]$ through another node k and if $u_i + d_{ij} < u_j$, replace $[u_j, k]$ with $[u_i + d_{ij}, i]$.
(b) If all nodes have permanent labels, stop. Otherwise, select the label $[u_r, s]$ having the shortest distance ($=u_r$) among all the temporary labels (break ties arbitrarily). Set $i = r$ and repeat step i.

To model the rules of transition in the scenario and to run Dijkstra's algorithm more effectively for organizations with many positions, we calculated the shortest-path tree of the network in Fig. 4 separately for branches T, I and S. These shortest path trees

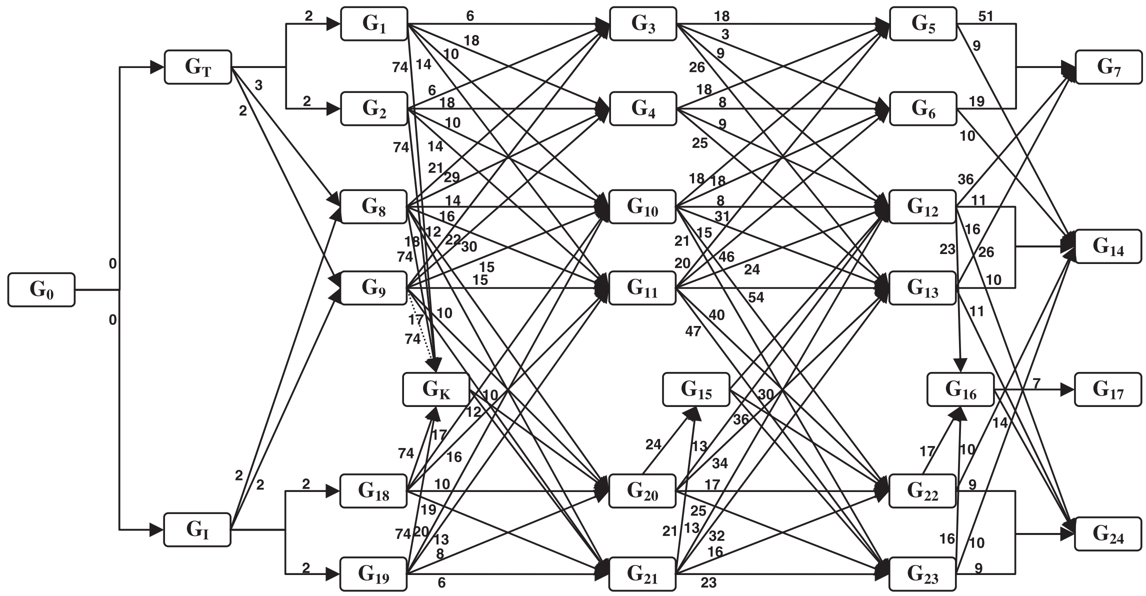

Fig. 4. Network flow model for scenario.

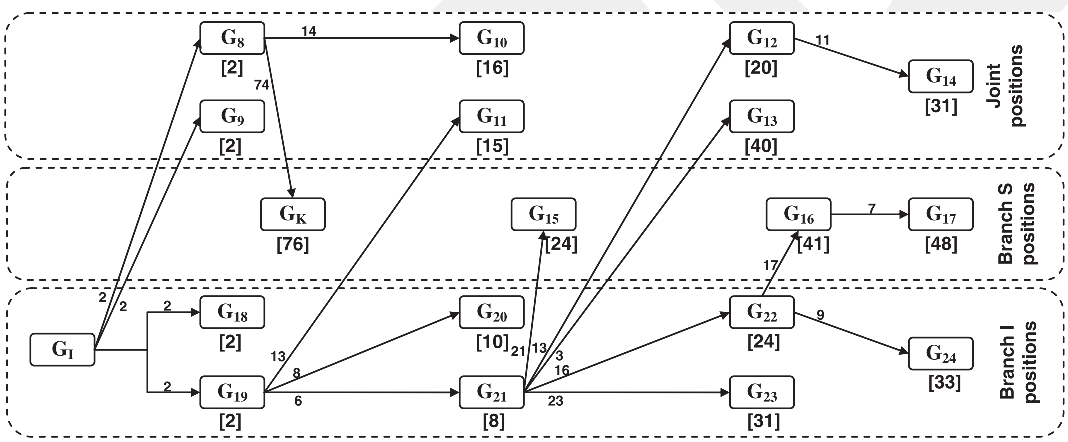

Fig. 5. Shortest path tree of branch I.

show what the predecessor position should be for each position within the parameters of the scenario. For example, according to the shortest-path tree of branch I in Fig. 5, the predecessor positions back to front for G_{24} should be G_{22}, G_{21}, G_{19} and G_I. In this career path, 33 units of training are needed (the value indicated in the square bracket under G_{24}). We found the shortest paths for the joint positions by assessing the shortest-path trees together. For instance, we predicated the shortest path of joint position G_{14} on branch T's shortest-path tree and found that 21 units of training are needed. The training need would be 31 units if we based the calculation on branch I's shortest-path tree.

Finally, the organization has functional information for the assignment process that could be used with other criteria such as education, rank, foreign language, penalty, and health status. Information based on cost-effective training needs is summarized in Table 5. In the table, a value of "1" indicates the shortest path(s) (with the least training need) to the positions in the upper row from the positions in the leftmost column. A value of "0" indicates longer paths. For example, we found the predecessor positions G_1, G_2 and G_{19} to have the same low cost for G_{11}. In this context, a value of "1" was allocated to table cells (G_1; G_{11}), (G_2; G_{11}) and (G_{19}; G_{11}). The data here, which is the output of the CECPM career matrix step, will be used as an input for the assignment step.

4.3. Assignment

It is necessary to ensure compatibility between a personnel's qualifications and a position's requirements; personnel less- or not suited for the job require more training. In the assignment process, hierarchical organizations commonly use criteria such as appraisal scores, penalty scores, health status, foreign language status, previous duties, and educational background, when deciding whom to place in a position. In addition organizations pay attention to personnel's preferences about the positions. Career paths and training costs should also be part of the criteria. To this end, we use the output of the career matrix step in Table 5 as an input for the CECPM assignment step. We aim to decrease training costs by making career matrix one of the inputs of the assignment procedure. The following factors are considered when integrating career matrix into the assignment process:

- The career matrix should not change the organization's traditional assignment principles.
- The career matrix should be compatible with the other criteria used in the traditional assignment process and, using an appropriate method, integrated with them according to its importance.

Table 5
Career matrix based on cost-effective training needs.

BRANCH		T								I								Joint Positions							S			
	POSITION	GU	G1	G2	G3	G4	G5	G6	G7	GP	G18	G19	G20	G21	G22	G23	G24	G8	G9	G10	G11	G12	G13	G14	GK	G15	G16	G17
T	GU	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0
	G1	0	0	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	**1**	0	0	0
	G2	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	**1**	0	0	0
	G3	0	0	0	0	0	**1**	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0
	G4	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G6	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0
	G7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	GP	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0	**1**	**1**	0	0	0	0	0	0	0	0	0
	G18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0
	G19	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0	0	**1**	0	0	0	**1**	0	0	0
	G20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G21	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	**1**	0	0	0	0	0	0	0	0	0	**1**	0	0
	G22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0	0	0	0	0	0	0	0	0
	G23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Joint Positions	G8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0
	G9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0	0	0
	G10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**	0
	G13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
S	GK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
	G17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

- The personnel's preference(s) of position and compatibility with the position(s) should also be considered.

We integrated career matrix into the criteria using the AHP. We used LP to model the assignment process, considering employee position compatibility and preferences, and we employed Pareto optimality analysis to determine a reasonable weight for personnel's preferences.

4.3.1. Employing career matrix as assignment criterion

The AHP, developed by Thomas L. Saaty in the 1970s, is commonly applied to decision problems. It provides a comprehensive and rational framework for structuring a decision problem, for representing and quantifying its elements, for relating those elements to overall goals and for evaluating alternative solutions. Thus, we decided to use the AHP to organize and analyze the assignment process. Below we show the basic steps of AHP as applied in the CECPM (see Saaty, 2008):

Step 1: Model the problem as a hierarchy containing the decision goal, the alternatives for reaching it and the criteria for evaluating the alternatives.
Step 2: Establish priorities among the elements of the hierarchy by making a series of judgments based on pair wise comparisons of the elements.
Step 3: Synthesize these judgments to yield a set of overall priorities for the hierarchy.
Step 4: Check the consistency of the judgments.
Step 5: Come to a final decision based on the results of this process.

4.3.1.1. Hierarchical model of the assignment process. Inspired by Korkmaz et al. (2008), we developed a hierarchical model of the assignment process to model commonly used criteria and enable the comparison studies mentioned in Section 4.3.3. The model consists of an objective, criteria and sub-criteria, as shown in Fig. 6. All commonly used criteria in the assignment process were attached to the model. The "Previous Duty" sub-criterion was designed to incorporate the career matrix into the assignment process.

4.3.1.2. Weighting the criteria. After we developed the hierarchical model, we set the criteria for achieving the goal through pair wise comparisons. The order of the criteria were determined using a scale of 1–9 (1: equal, 3: slightly superior, 5: strongly superior, 7: very strongly superior and 9: ultimately superior, with 2, 4, 6 and 8 the intermediate values). The criteria were then transformed into weights between $[0, 1]$ after some calculations (see Bhushan & Kanwal, 2004; Saaty, 1980, 2000, 2008). For the calculations we used Expert Choice (see Expert Choice, 2009) software, which can also compute a reasonable consistency ratio for weights in a hierarchical model. Table 6 shows the results of implementation of the AHP.

Note that we applied a different computation for the weights of the "Previous Duty" sub-criterion. Instead of computing the weight of each sub-criterion with the AHP, we allocated the total weight of

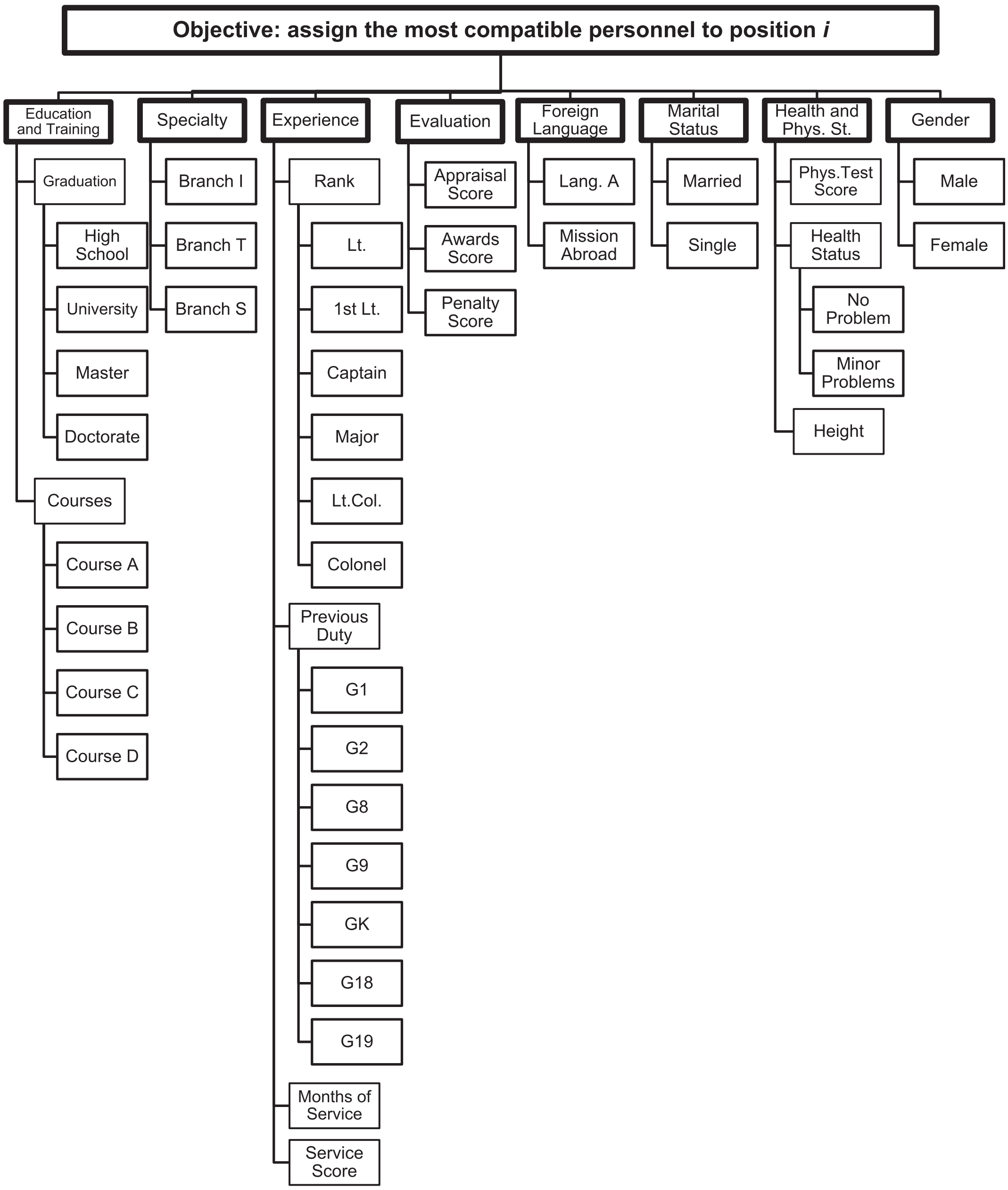

Fig. 6. Hierarchical model of assignment process (for the 2nd level positions).

"Previous Duty" to position(s) with the minimum training cost according to the career matrix, and "0" to other positions.

In the method we have preferred in determining the weights one should perform $m \times n\,(n-1)/2$ pair wise comparisons, where m is the number of positions (to be assigned to) and n is the number of criteria. The weights in Table 6, which are needed for our scenario, have been obtained by making $16 \times 39 \times 38/2 = 11{,}856$ pair wise comparisons. Since these pair wise comparisons are made manually, scalability is an issue in the weighting procedure. For large hierarchical organizations, there may be a need for decomposition to reduce the number of comparisons. Thus depending on the structure of the organization or the desired precision of the results, weights can be calculated only for clusters of positions (i.e. weights can be calculated for the set of the positions belonging to the same branch instead of calculating for each position separately) or depending on the characteristics of the criteria, they can be clustered to do pair wise comparisons only for a limited number of criteria sets (i.e. weights can be calculated for main criteria and then these weights can be equally portioned to the sub-criteria instead of calculating the weights for each sub-criteria separately). Another way to increase the applicability of our CEC-PM to large hierarchical organizations is to change the technique used for weighting the criteria. Instead of AHP, other techniques such as direct point allocation, simple multiattribute rating technique (SMART), technique for order preference by similarity to ideal solution (TOPSIS), swing weighting, tradeoff weighting etc. can be preferred to prevent expending energy on computing the weights. For a comprehensive literature review about the weighting methods readers may refer to Toloie-Eshlaghy, Homayonfar, Aghaziarati, and Arbabiun (2011). Pöyhönen and Hämäläinen (2001) compared several multiattribute weighting techniques but could not determine a clear winner. According to Pöyhönen and

Table 6
Criteria weights.

Criteria		Branch T positions					Branch I positions					Joint positions					Pos. S.
		G_3	G_4	G_5	G_6	G_7	G_{20}	G_{21}	G_{22}	G_{23}	G_{24}	G_{10}	G_{11}	G_{12}	G_{13}	G_{14}	G_{17}
Education	High School	0.001	0.001	0.002	0.001	0.001	0.0007	0.0008	0.0007	0.001	0.001	0.001	0.0009	0.002	0.003	0.005	0.002
	University	0.025	0.025	0.026	0.017	0.021	0.01	0.021	0.013	0.019	0.021	0.026	0.024	0.031	0.042	0.083	0.036
	Master	0.005	0.005	0.005	0.003	0.005	0.004	0.004	0.003	0.004	0.005	0.005	0.005	0.006	0.008	0.021	0.009
	Doctorate	0.003	0.003	0.005	0.003	0.004	0.003	0.003	0.003	0.004	0.004	0.004	0.003	0.006	0.008	0.016	0.007
Courses[a]	Course A/E/I	0.018	0.018	0.035	0.012	0.014	0.028	0.016	0.001	0.003	0.007	0.039	0.0007	0.011	0.021	0.031	0.029
	Course B/F/J	0.0003	0.0003	0.012	0.002	0.005	0.0003	0.0001	0.002	0.002	0.006	0.0004	0.01	0.024	0.033	0.031	0.014
	Course C/G/K	0.021	0.021	0.004	0.019	0.011	0.0003	0.0001	0.0007	0.001	0.006	0.0004	0.0002	0.012	0.015	0.031	0.037
	Course D/H/L	0.0002	0.0002	0.002	0.001	0.033	0.0003	0.016	0.028	0.032	0.022	0.0004	0.026	0.015	0.015	0.031	0.004
Speciality	T	0.137	0.137	0.156	0.243	0.231	0.001	0.001	0.002	0.001	0.002	0.042	0.015	0.039	0.054	0.04	0.002
	I	0.001	0.001	0.002	0.002	0.002	0.122	0.136	0.069	0.114	0.188	0.042	0.015	0.045	0.054	0.037	0.002
	S	0.001	0.001	0.002	0.002	0.002	0.001	0.001	0.01	0.001	0.002	0.0004	0.0001	0.018	0.0005	0.02	0.158
Rank	Lieutenant	0.0008	0.0008	0.0008	0.0004	0.0008	0.0009	0.0009	0.0003	0.0005	0.0009	0.0009	0.001	0.0005	0.0005	0.0005	0.0006
	1st Lieutenant	0.003	0.003	0.0008	0.0004	0.0008	0.004	0.004	0.0003	0.0005	0.0009	0.004	0.006	0.0005	0.0005	0.0005	0.0006
	Captain	0.106	0.104	0.0008	0.0004	0.0008	0.121	0.116	0.0003	0.0005	0.0009	0.115	0.185	0.0005	0.0005	0.0005	0.0006
	Major	0.001	0.001	0.083	0.047	0.0008	0.001	0.001	0.035	0.051	0.0009	0.001	0.002	0.055	0.053	0.0005	0.0006
	Lt. Colonel	0.0007	0.0007	0.077	0.044	0.0008	0.0008	0.0008	0.032	0.048	0.0009	0.0008	0.001	0.051	0.049	0.0005	0.0006
	Colonel	0.0005	0.0005	0.0008	0.0004	0.087	0.0006	0.0006	0.0003	0.0005	0.09	0.0005	0.0009	0.0005	0.0005	0.057	0.066
Previous duty[a]	G1/G3/G5	0.12	0.225	0.075	0.1	0	0	0	0	0	0	0.065	0.11	0.18	0.013	0	0
	G2/G4/G6	0.12	0	0.075	0	0.096	0	0	0	0	0	0.065	0.11	0	0	0.057	0
	G8/G10/G12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	G9/G11/G13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	GS/G15/G16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.066
	G18/G20/G22	0	0	0	0	0	0	0	0.075	0.15	0.09	0	0	0	0	0	0
	G19/G21/G23	0	0	0	0	0	0.182	0.168	0	0	0	0	0.11	0	0	0	0
Experience	Months of Service	0.051	0.058	0.082	0.047	0.049	0.046	0.085	0.028	0.05	0.039	0.076	0.134	0.054	0.052	0.024	0.028
	Service Score	0.042	0.051	0.083	0.047	0.043	0.076	0.1	0.025	0.051	0.038	0.083	0.127	0.054	0.053	0.024	0.028
Evaluation	Appraisal Score	0.034	0.034	0.017	0.046	0.038	0.033	0.033	0.02	0.037	0.032	0.051	0.015	0.035	0.029	0.037	0.046
	Awards Score	0.022	0.022	0.011	0.03	0.034	0.022	0.022	0.016	0.024	0.036	0.034	0.014	0.037	0.025	0.037	0.046
	Penalty Score	0.044	0.044	0.022	0.059	0.051	0.043	0.043	0.028	0.047	0.048	0.066	0.015	0.041	0.036	0.037	0.046
Foreign language	Language A	0.015	0.015	0.025	0.024	0.03	0.022	0.024	0.013	0.03	0.029	0.014	0.008	0.032	0.033	0.051	0.077
	Mission Abroad	0.015	0.015	0.025	0.024	0.03	0.022	0.024	0.013	0.03	0.029	0.014	0.008	0.032	0.033	0.051	0.077
Marital status	Married	0.015	0.015	0.026	0.022	0.024	0.017	0.018	0.021	0.043	0.023	0.019	0.011	0.043	0.045	0.05	0.036
	Single	0.015	0.015	0.026	0.022	0.024	0.017	0.018	0.041	0.066	0.023	0.019	0.011	0.043	0.045	0.05	0.036
Health and physical status	Physical Test Sc.	0.038	0.038	0.015	0.031	0.023	0.044	0.022	0.118	0.031	0.057	0.022	0.008	0.026	0.027	0.028	0.023
	Minor Problems	0.026	0.026	0.007	0.01	0.015	0.022	0.011	0.023	0.017	0.024	0.013	0.004	0.021	0.013	0.009	0.012
	No Problem	0.026	0.026	0.007	0.01	0.028	0.022	0.011	0.127	0.032	0.047	0.013	0.004	0.021	0.013	0.018	0.012
	Height	0.018	0.018	0.007	0.014	0.014	0.038	0.019	0.057	0.031	0.017	0.078	0.008	0.026	0.027	0.028	0.023
Gender	Male	0.045	0.045	0.023	0.097	0.041	0.075	0.068	0.185	0.08	0.073	0.082	0.011	0.087	0.048	0.044	0.036
	Female	0.017	0.017	0.023	0.015	0.033	0.0007	0.0006	0.008	0.041	0.033	0.0008	0.011	0.087	0.048	0.044	0.036
Total	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

[a] Sub-criteria in this part should be read according to relevant level.

Table 7
Positions' preference list (career matrix based "previous duty" criterion).

Order	Branch T Positions					Branch I Positions					Joint Positions					Pos. S.
	G3	G4	G5	G6	G7	G20	G21	G22	G23	G24	G10	G11	G12	G13	G14	G17
1	Per.15	Per.7	Per.36	Per.43	Per.93	Per.18	Per.18	Per.62	Per.36	Per.93	Per.7	Per.25	Per.62	Per.53	Per.93	Per.93
2	Per.7	Per.2	Per.42	Per.36	Per.73	Per.21	Per.25	Per.39	Per.62	Per.88	Per.27	Per.27	Per.56	Per.62	Per.97	Per.105
3	Per.2	Per.15	Per.43	Per.42	Per.71	Per.20	Per.20	Per.56	Per.42	Per.91	Per.8	Per.26	Per.53	Per.56	Per.71	Per.101
4	Per.8	Per.8	Per.37	Per.38	Per.85	Per.17	Per.21	Per.60	Per.39	Per.95	Per.28	Per.23	Per.63	Per.60	Per.91	Per.103
5	Per.3	Per.1	Per.48	Per.37	Per.78	Per.25	Per.26	Per.36	Per.56	Per.97	Per.13	Per.19	Per.64	Per.55	Per.95	Per.102
6	Per.1	Per.16	Per.41	Per.41	Per.77	Per.26	Per.17	Per.53	Per.60	Per.98	Per.1	Per.18	Per.59	Per.52	Per.88	Per.104
7	Per.16	Per.3	Per.39	Per.51	Per.72	Per.23	Per.23	Per.42	Per.53	Per.90	Per.2	Per.4	Per.52	Per.54	Per.73	Per.71
8	Per.11	Per.11	Per.46	Per.50	Per.76	Per.22	Per.19	Per.43	Per.43	Per.96	Per.20	Per.7	Per.70	Per.63	Per.105	Per.76
9	Per.9	Per.9	Per.50	Per.48	Per.83	Per.19	Per.27	Per.38	Per.41	Per.89	Per.18	Per.17	Per.61	Per.58	Per.76	Per.91
10	Per.10	Per.10	Per.51	Per.46	Per.86	Per.24	Per.24	Per.41	Per.51	Per.87	Per.17	Per.20	Per.60	Per.64	Per.77	Per.73
11	Per.6	Per.6	Per.38	Per.45	Per.79	Per.27	Per.22	Per.48	Per.48	Per.94	Per.6	Per.1	Per.37	Per.65	Per.85	Per.85
12	Per.13	Per.13	Per.44	Per.47	Per.82	Per.28	Per.28	Per.55	Per.38	Per.99	Per.21	Per.8	Per.42	Per.59	Per.101	Per.97
13	Per.12	Per.12	Per.40	Per.40	Per.80	Per.29	Per.29	Per.63	Per.55	Per.100	Per.25	Per.13	Per.55	Per.61	Per.74	Per.95
14	Per.4	Per.4	Per.49	Per.39	Per.84	Per.30	Per.30	Per.51	Per.46	Per.92	Per.26	Per.24	Per.66	Per.57	Per.78	Per.78
15	Per.14	Per.14	Per.45	Per.44	Per.74	Per.7	Per.7	Per.52	Per.37	Per.105	Per.23	Per.21	Per.46	Per.70	Per.83	Per.88
16	Per.5	Per.5	Per.47	Per.49	Per.81	Per.13	Per.13	Per.47	Per.64	Per.101	Per.15	Per.6	Per.47	Per.67	Per.86	Per.77
17	Per.27	Per.27	Per.62	Per.62	Per.75	Per.6	Per.35	Per.54	Per.52	Per.102	Per.12	Per.16	Per.58	Per.42	Per.103	Per.83
18	Per.18	Per.18	Per.60	Per.60	Per.105	Per.35	Per.6	Per.70	Per.54	Per.103	Per.29	Per.12	Per.54	Per.48	Per.82	Per.74
19	Per.21	Per.20	Per.56	Per.56	Per.88	Per.8	Per.8	Per.49	Per.50	Per.73	Per.30	Per.22	Per.65	Per.43	Per.102	Per.86
20	Per.20	Per.21	Per.53	Per.53	Per.97	Per.1	Per.1	Per.64	Per.63	Per.83	Per.16	Per.5	Per.57	Per.68	Per.98	Per.90
21	Per.35	Per.17	Per.55	Per.70	Per.95	Per.15	Per.32	Per.58	Per.58	Per.76	Per.11	Per.9	Per.67	Per.36	Per.87	Per.82
22	Per.17	Per.35	Per.68	Per.67	Per.91	Per.2	Per.15	Per.37	Per.47	Per.84	Per.3	Per.29	Per.69	Per.37	Per.72	Per.72
23	Per.25	Per.25	Per.64	Per.68	Per.101	Per.31	Per.2	Per.67	Per.44	Per.82	Per.35	Per.28	Per.68	Per.38	Per.90	Per.87
24	Per.28	Per.28	Per.66	Per.55	Per.103	Per.32	Per.12	Per.46	Per.49	Per.78	Per.10	Per.30	Per.43	Per.41	Per.81	Per.98
25	Per.26	Per.26	Per.52	Per.63	Per.102	Per.33	Per.31	Per.50	Per.70	Per.85	Per.31	Per.11	Per.48	Per.66	Per.99	Per.84
26	Per.23	Per.23	Per.65	Per.66	Per.98	Per.12	Per.33	Per.68	Per.40	Per.77	Per.22	Per.15	Per.38	Per.47	Per.79	Per.81
27	Per.32	Per.32	Per.63	Per.64	Per.89	Per.11	Per.34	Per.66	Per.61	Per.72	Per.33	Per.2	Per.36	Per.46	Per.84	Per.99
28	Per.31	Per.31	Per.70	Per.58	Per.90	Per.16	Per.16	Per.44	Per.65	Per.74	Per.19	Per.14	Per.41	Per.39	Per.89	Per.96
29	Per.29	Per.29	Per.58	Per.52	Per.87	Per.3	Per.3	Per.61	Per.66	Per.71	Per.14	Per.3	Per.50	Per.51	Per.75	Per.100
30	Per.33	Per.33	Per.67	Per.65	Per.99	Per.34	Per.10	Per.65	Per.45	Per.86	Per.24	Per.10	Per.51	Per.50	Per.96	Per.75
31	Per.34	Per.34	Per.61	Per.69	Per.96	Per.10	Per.11	Per.45	Per.68	Per.104	Per.32	Per.35	Per.45	Per.45	Per.100	Per.79
32	Per.30	Per.30	Per.57	Per.59	Per.100	Per.9	Per.4	Per.59	Per.67	Per.75	Per.4	Per.32	Per.40	Per.69	Per.92	Per.92
33	Per.24	Per.19	Per.69	Per.61	Per.104	Per.4	Per.9	Per.40	Per.59	Per.80	Per.9	Per.31	Per.49	Per.40	Per.80	Per.80
34	Per.19	Per.24	Per.54	Per.54	Per.94	Per.14	Per.14	Per.57	Per.57	Per.79	Per.5	Per.34	Per.44	Per.49	Per.94	Per.89
35	Per.22	Per.22	Per.59	Per.57	Per.92	Per.5	Per.5	Per.69	Per.69	Per.81	Per.34	Per.33	Per.39	Per.44	Per.104	Per.94

Hämäläinen (2001) the choice of weighting technique may not matter much in outcome and the practitioners can indeed choose a method following their personal preferences. Thus other weighting techniques, which enables computing the weights with fewer judgments (e.g. $n-1$ comparisons for each position) can be preferred when needed.

4.3.2. Performance values of the alternatives

We used performance values to measure a personnel's compatibility with a position. The performance value of assigning personnel i to position j was calculated with the formula below:

$$k_{ij} = \sum_{c=1}^{n} a_{jc} b_{ic} \quad \forall i, \quad \forall j \tag{1}$$

where k_{ij} is the performance value when personnel i is assigned to position j; i the personnel number ($i = 1, \ldots, p$); j the position number ($j = 1, \ldots, m$); c the criterion number ($c = 1, \ldots, n$); a_{jc} the weight of criterion c for position j and b_{ic} the score of personnel i for criterion c.

In the scenario, performance values for 105 personnel waiting for assignments were calculated using the qualification values (b_{ic}) in Table 2 and the weights (a_{jc}) in Table 6. Preference list of a position (Table 7) was obtained by sorting personnel into descending order according to their performance values. This preference list contains the personnel (who can be assigned to a particular position according to parameters of the scenario) ordered according to their degree of suitability to that position. The grey cells in Table 7 indicate personnel which could be assigned to the related position according to the parameters of the scenario. For example, the most compatible personnel for position G_{17} are Per.105, Per.101, Per.103, Per.102 and Per.104, in that order.

Table 8
Positions' preference list (AHP based "previous duty" criterion).

Order	Branch T Positions					Branch I Positions					Joint Positions					Pos. S
	G3	G4	G5	G6	G7	G20	G21	G22	G23	G24	G10	G11	G12	G13	G14	G17
1	Per.7	Per.7	Per.60	Per.53	Per.93	Per.25	Per.25	Per.60	Per.60	Per.93	Per.7	Per.25	Per.46	Per.50	Per.93	Per.93
2	Per.2	Per.2	Per.54	Per.60	Per.73	Per.26	Per.26	Per.54	Per.54	Per.88	Per.8	Per.26	Per.49	Per.64	Per.73	Per.105
3	Per.8	Per.8	Per.53	Per.54	Per.85	Per.23	Per.23	Per.53	Per.53	Per.91	Per.1	Per.23	Per.37	Per.46	Per.85	Per.101
4	Per.1	Per.1	Per.61	Per.61	Per.7	Per.22	Per.24	Per.44	Per.44	Per.90	Per.2	Per.24	Per.63	Per.37	Per.71	Per.103
5	Per.16	Per.16	Per.44	Per.44	Per.80	Per.24	Per.22	Per.61	Per.61	Per.89	Per.16	Per.22	Per.56	Per.49	Per.97	Per.102
6	Per.6	Per.6	Per.55	Per.62	Per.81	Per.18	Per.27	Per.49	Per.49	Per.87	Per.13	Per.27	Per.50	Per.40	Per.91	Per.104
7	Per.13	Per.13	Per.62	Per.58	Per.71	Per.27	Per.18	Per.59	Per.59	Per.95	Per.20	Per.19	Per.65	Per.56	Per.95	Per.71
8	Per.15	Per.15	Per.59	Per.55	Per.76	Per.21	Per.20	Per.63	Per.63	Per.97	Per.27	Per.18	Per.70	Per.63	Per.88	Per.76
9	Per.12	Per.12	Per.52	Per.48	Per.78	Per.20	Per.21	Per.50	Per.50	Per.98	Per.18	Per.4	Per.68	Per.41	Per.105	Per.91
10	Per.3	Per.4	Per.48	Per.36	Per.83	Per.17	Per.17	Per.56	Per.56	Per.96	Per.17	Per.7	Per.51	Per.65	Per.76	Per.73
11	Per.4	Per.3	Per.58	Per.52	Per.77	Per.28	Per.28	Per.62	Per.62	Per.99	Per.6	Per.17	Per.64	Per.51	Per.77	Per.85
12	Per.11	Per.11	Per.57	Per.57	Per.72	Per.29	Per.29	Per.55	Per.55	Per.100	Per.25	Per.1	Per.61	Per.70	Per.101	Per.95
13	Per.9	Per.9	Per.39	Per.42	Per.82	Per.30	Per.19	Per.58	Per.58	Per.94	Per.21	Per.20	Per.40	Per.38	Per.81	Per.97
14	Per.10	Per.10	Per.43	Per.59	Per.84	Per.19	Per.30	Per.41	Per.70	Per.92	Per.28	Per.8	Per.54	Per.47	Per.79	Per.78
15	Per.14	Per.14	Per.36	Per.39	Per.74	Per.7	Per.7	Per.68	Per.52	Per.105	Per.26	Per.13	Per.52	Per.68	Per.78	Per.88
16	Per.5	Per.5	Per.42	Per.43	Per.86	Per.13	Per.13	Per.70	Per.41	Per.101	Per.23	Per.9	Per.45	Per.67	Per.74	Per.77
17	Per.27	Per.27	Per.49	Per.50	Per.75	Per.6	Per.35	Per.67	Per.51	Per.73	Per.15	Per.16	Per.36	Per.54	Per.83	Per.83
18	Per.18	Per.18	Per.63	Per.49	Per.105	Per.35	Per.6	Per.66	Per.48	Per.78	Per.29	Per.21	Per.41	Per.55	Per.86	Per.74
19	Per.21	Per.20	Per.50	Per.63	Per.88	Per.8	Per.8	Per.51	Per.147	Per.83	Per.30	Per.12	Per.38	Per.53	Per.103	Per.86
20	Per.20	Per.21	Per.56	Per.56	Per.95	Per.1	Per.1	Per.45	Per.65	Per.76	Per.12	Per.6	Per.47	Per.60	Per.102	Per.90
21	Per.35	Per.17	Per.66	Per.68	Per.97	Per.15	Per.32	Per.47	Per.64	Per.102	Per.35	Per.28	Per.67	Per.61	Per.82	Per.72
22	Per.17	Per.35	Per.45	Per.67	Per.91	Per.2	Per.15	Per.65	Per.39	Per.85	Per.11	Per.5	Per.69	Per.58	Per.72	Per.82
23	Per.25	Per.25	Per.41	Per.66	Per.101	Per.31	Per.2	Per.64	Per.36	Per.103	Per.3	Per.29	Per.53	Per.66	Per.87	Per.87
24	Per.28	Per.28	Per.68	Per.41	Per.103	Per.32	Per.12	Per.52	Per.68	Per.77	Per.31	Per.11	Per.55	Per.62	Per.98	Per.98
25	Per.26	Per.26	Per.51	Per.45	Per.102	Per.33	Per.31	Per.48	Per.43	Per.72	Per.33	Per.15	Per.66	Per.45	Per.90	Per.84
26	Per.23	Per.23	Per.67	Per.65	Per.98	Per.12	Per.33	Per.36	Per.57	Per.84	Per.10	Per.2	Per.58	Per.52	Per.80	Per.81
27	Per.32	Per.32	Per.70	Per.64	Per.89	Per.11	Per.34	Per.39	Per.38	Per.82	Per.22	Per.14	Per.60	Per.36	Per.99	Per.99
28	Per.31	Per.31	Per.64	Per.51	Per.90	Per.16	Per.16	Per.43	Per.45	Per.71	Per.32	Per.30	Per.62	Per.59	Per.84	Per.96
29	Per.29	Per.29	Per.65	Per.70	Per.87	Per.3	Per.3	Per.38	Per.37	Per.74	Per.19	Per.35	Per.48	Per.44	Per.89	Per.100
30	Per.33	Per.33	Per.38	Per.38	Per.96	Per.34	Per.10	Per.37	Per.66	Per.86	Per.24	Per.3	Per.44	Per.48	Per.75	Per.75
31	Per.34	Per.34	Per.37	Per.69	Per.99	Per.10	Per.11	Per.42	Per.67	Per.80	Per.9	Per.10	Per.42	Per.42	Per.96	Per.79
32	Per.30	Per.30	Per.69	Per.46	Per.100	Per.9	Per.4	Per.46	Per.42	Per.104	Per.14	Per.32	Per.57	Per.57	Per.100	Per.92
33	Per.24	Per.19	Per.40	Per.37	Per.104	Per.4	Per.9	Per.57	Per.46	Per.75	Per.4	Per.31	Per.43	Per.69	Per.92	Per.80
34	Per.19	Per.24	Per.47	Per.47	Per.94	Per.14	Per.14	Per.40	Per.40	Per.79	Per.5	Per.34	Per.39	Per.39	Per.104	Per.89
35	Per.22	Per.22	Per.46	Per.40	Per.92	Per.5	Per.5	Per.69	Per.69	Per.81	Per.34	Per.33	Per.59	Per.43	Per.94	Per.94

4.3.3. Assignments and comparisons

In organizations with a large number of personnel and a diversity of positions, the following factors should be considered in the assignment process:

- Placing the best-fitting personnel in a position.
- Satisfying personnel preferences about the positions.
- Decreasing detailers' (HR staff implementing the assignment) workloads and biases.

We used LP in the assignment step of the CECPM. To evaluate its efficiency, its output was compared against the two-sided matching model proposed by Korkmaz et al. (2008) under the same scenario. Tan and Yeong (2001), Wasmund (2001), Koh (2002), and Korkmaz et al. (2008) claim that two-sided matching increases the quality of assignments and decreases the number of personnel and time needed for the assignment process when compared to a manual assignment process. Related studies showed that the quality of assignment decisions is well summarized in the desire to put the right personnel in the right place while satisfying the personnel's preferences. Therefore in our study, assignment quality was evaluated according to two performance criteria: (1) the amount of compatibility between the positions and the personnel's qualifications and (2) the number of personnel satisfied with their assignments. Since the aim of this study is to set forth a chain of methodologies (CECPM) for HRM functions that re-forms training needs to decrease training costs, the first performance criterion was evaluated in terms of training need, which is directly proportional to person-to-position compatibility. The LP model in our CECPM assigns the personnel to the positions depending on their performance values (k_{ij}). As seen in formula (1) performance values are the summation of the multiplication of weight of criterion c for position j (a_{jc}) and score of personnel i for criterion c (b_{ic}) for each criterion. One of the essentials to constitute a positive change in the performance value is to have a high score for the previous duty criterion. To determine a training need, one compares personnel qualifications with position competencies, especially the previous duties of the personnel. High score for the previous duty criterion means less training need for our model, and this is what we are trying to achieve with CECPM. Assigning the personnel with high score for previous duty criterion to the related position is therefore important but not everything. All commonly used criteria should be considered while forming person-to-position compatibility. To this respect the assignment step in CECPM works with performance values but the quality of solution is evaluated according to the amount of training need for which our CECPM is intended. The second performance criterion was evaluated with the number of personnel assigned to their first preferences. A rational assignment process should consider the personnel's preferences about the positions. Satisfying person-to-position compatibility is important for the organization but the goals and voluntariness of the personnel is another significant factor which usually contradicts person-to-position compatibility. The individual preferences of a person is the outcome of a complex decision making process. This process generally optimizes too many familial needs and career objectives at the same time. Therefore assigning a person to his/her first preference, while satisfying person-to-position compatibility, is a good sign of the fact that both the organization and the person win. Since the number of personnel assigned to their first preference is a clear and present indicator of the personnel satisfied with their assignments we used this measure in the evaluations.

In two-sided matching, there are two categories of agents. Each agent seeks an acceptable match with an agent from the other category and both agents' preferences are important (Korkmaz et al., 2008). In this method the particular match may depend on which group submits the proposal. During implementation, we had two assumptions: (1) the proposing group is the set of empty positions and (2) the number of empty positions equals the number of personnel waiting for assignment. In the CECPM assignment step, we used EP-Match, a Microsoft Excel application developed by Barron and Vardy (2004), to implement two-sided matching (see Barron and Vardy (2004) for the algorithm).

We first ran EP-Match with the appropriate criteria, with the weights calculated through AHP, as per Korkmaz et al. (2008). Therefore, the preference list in Table 8 was used for the position preferences and for the personnel's preferences we randomly ordered possible positions to which each personnel could be assigned. The results are presented in Table 9.

We present the needed training units for assigning personnel i from position j to position k in Table 9. These training needs result from the data derived from Table 4. For instance, assigning Per.1 from position G_1–G_4 results in 18 units of training needed. According to Table 9, the total amount of training needed for assignments from first-level positions to second-level positions is 501 units.

Table 9
Assignments.

Assignments from 1st Level to 2nd Level				Assignments from 2nd Level to 3rd Level				Assignments from 3rd Level to 4th Level			
Personnel	Former position	Current position	Training need	Personnel	Former position	Current position	Training need	Personnel	Former position	Current position	Training need
Per.1	G1	G4	18	Per.36	G3	G6	3	Per.71	G5	G7	51
Per.2	G1	G3	6	Per.37	G3	G5	18	Per.72	G5	G14	9
Per.3	G2	G10	10	Per.38	G4	G12	9	Per.73	G6	G14	10
Per.4	G8	G4	29	Per.39	G10	G5	18	Per.74	G12	G14	11
Per.5	G9	G11	15	Per.40	G11	G13	54	Per.75	G13	G14	10
Per.6	G9	G4	30	Per.41	G11	G6	46	Per.76	G13	G14	10
Per.7	G1	G3	6	Per.42	G3	G5	18	Per.77	G5	G7	51
Per.8	G1	G3	6	Per.43	G3	G5	18	Per.78	G5	G14	9
Per.9	G2	G3	6	Per.44	G4	G5	18	Per.79	G6	G7	19
Per.10	G2	G3	6	Per.45	G4	G12	9	Per.80	G6	G14	10
Per.11	G2	G10	10	Per.46	G4	G12	9	Per.81	G6	G14	10
Per.12	G8	G4	29	Per.47	G10	G6	18	Per.82	G12	G14	11
Per.13	G9	G10	15	Per.48	G11	G12	24	Per.83	G13	G7	26
Per.14	G8	G10	14	Per.49	G10	G6	18	Per.84	G12	G7	36
Per.15	G2	G4	18	Per.50	G4	G6	8	Per.85	G6	G7	19
Per.16	G1	G10	10	Per.51	G3	G12	9	Per.86	G5	G7	51
Per.17	G18	G21	19	Per.52	G20	G23	25	Per.87	G22	G24	9
Per.18	G18	G20	10	Per.53	G20	G22	17	Per.88	G22	G14	10
Per.19	G18	G11	16	Per.54	G20	G13	34	Per.89	G22	G24	9
Per.20	G18	G20	10	Per.55	G20	G22	17	Per.90	G22	G14	10
Per.21	G18	G10	17	Per.56	G20	G22	23	Per.91	G22	G24	9
Per.22	G19	G10	20	Per.57	G21	G23	23	Per.92	G23	G24	9
Per.23	G19	G10	20	Per.58	G21	G22	16	Per.93	G23	G24	9
Per.24	G19	G11	13	Per.59	G21	G23	23	Per.94	G23	G14	10
Per.25	G19	G11	13	Per.60	G21	G13	32	Per.95	G23	G14	10
Per.26	G19	G10	20	Per.61	G21	G23	23	Per.96	G23	G24	9
Per.27	G8	G21	18	Per.62	G10	G23	21	Per.97	G12	G24	16
Per.28	G8	G11	16	Per.63	G10	G13	31	Per.98	G12	G14	11
Per.29	G9	G11	15	Per.64	G11	G13	54	Per.99	G13	G24	11
Per.30	G9	G20	10	Per.65	G11	G22	40	Per.100	G13	G14	10
Per.31	GK	G20	10	Per.66	G15	G22	30	Per.101	G16	G24	14
Per.32	GK	G21	12	Per.67	G15	G22	30	Per.102	G16	G17	7
Per.33	GK	G21	12	Per.68	G15	G23	36	Per.103	G16	G17	7
Per.34	GK	G20	10	Per.69	G15	G12	17	Per.104	G16	G17	7
Per.35	GK	G21	12	Per.70	G15	G23	36	Per.105	G16	G24	14
Total training need:			501	Total training need:			825	Total training need:			534

Table 10
Comparative assignment results.

Assignments	Method				Difference	
	Two-sided matching (AHP)		Two-sided matching (career matrix)			
	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit) (%)	# Of Pers. assigned to 1st preference (%)
From 1st level to 2nd level	501	24	489	23	−2.40	−4.17
From 2nd level to 3rd level	825	32	803	29	−2.67	−9.38
From 3rd level to 4th level	534	31	510	27	−4.49	−12.90
Total	1860	87	1802	79	−3.12	−9.20

Subsequently, we again ran EP-Match with the criteria weights calculated with AHP, except for the "Previous Duty" criterion; that weight was derived from the career matrix. Therefore, we used the preference list in Table 7 for position preferences and used the same ordering for personnel's preferences as in the scenario above. We show the results of this operation in Table 10. Compared to the assignments for which all weights were calculated with AHP, the assignments using the "Previous Duty" criterion weight derived from the career plan resulted in a 3.12% lower training need.

The criterion derived from the career matrix decreases training costs, but it results in other issues:

- The number of personnel assigned to their first preferences is quite high (i.e. 79 out of 105). However, this number is 9.2% lower than the matches fully made with AHP (i.e. 87 out of 105).
- Neither the decision maker nor the analyst can control the level of importance allocated to personnel preferences. This situation also applies to the other performance criterion, i.e. the amount of compatibility between personnel qualifications and positions.
- To match each personnel with a vacant position, an ordered list of each personnel's preference must be developed.

To solve the problems mentioned above and to provide a decision support system for the bi-objective problem of satisfying personnel's preferences and matching personnel to positions, we used the weighting method suggested by Zadeh (1963). In this method given the individual objectives ($Max\ z_1 = c_1x$, $Max\ z_2 = c_2x, \ldots, Max\ z_r = c_rx$), we use nonnegative weights $(w_1, w_2, \ldots, w_r)$ multiplied by the corresponding objective and then determine a composite objective by adding up the weighted objectives. Formally, we construct the composite objective as $Max\ z = \sum_{k=1}^{r} w_k c_k x$. This objective is then repeatedly optimized for different combinations of weights. If the decision maker is reasonably certain about the choice of weights, optimizing the composite objective function with that weight combination will result in the desired combination. Most of the time the decision maker will not be able to specify precise weights. We can then use the weighting method to approximate the efficient frontier. Clearly, using a large number of objectives will require many combinations of weights to be examined. However, practical models will have rarely more than half a dozen or so objectives. Ideally, the analyst will start by optimizing one objective at a time, while ignoring all others, i.e., he will employ weight vectors $w = [1, 0, \ldots, 0]$, $[0, 1, 0, \ldots, 0]$, $\ldots$, $[0, 0, \ldots, 0, 1]$ in r separate optimization runs. This will establish the extreme boundaries of the efficient frontier. Then, typically, in cooperation with the decision maker, the analyst will solve problems, in which the composite objective function is constructed by using weight combinations deemed reasonable by the decision maker. This alternating interactive process terminates when a solution is computed that the decision maker deems acceptable (Eiselt & Sandblom, 2007). The following LP model was built using this weighting method:

$$Max w_{KD} KD + w_{TP} TP \tag{2}$$

$$\sum_{j \in g_i} x_{ij} = 1, \quad \forall i \tag{3}$$

$$\sum_{i \in p_j} x_{ij} = s_j, \quad \forall j \tag{4}$$

$$KD - \sum_{i \in p_j} \sum_{j \in g_i} k_{ij} x_{ij} = 0 \tag{5}$$

$$TP - \sum_{i \in p_j} \sum_{j \in g_i} t_{ij} x_{ij} = 0 \tag{6}$$

$$x_{ij} \geqslant 0, \forall i, \forall j \tag{7}$$

where KD is the utility value; TP the personnel's preference; w_{KD} the weight of KD; w_{TP} the weight of TP; x_{ij} the 1 if personnel i is assigned to position j, 0 otherwise; s_j the number of position j available; k_{ij} the utility value of assigning person i to position j; t_{ij} the weight of person i's preference for position j (the weights calculated with AHP for the scenario are 0.564 for the first preference, 0.178 for the second preference, 0.130 for the third preference and 0.102 for the fourth and further preferences); g_i the set of the positions

Table 11
Comparison of assignments.

Assignments	Method						Difference (1,3)	
	1. Two-sided matching (AHP)		2. Two-sided matching (Career Matrix)		3. Linear programming (wTP=0)			
	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit) (%)	# Of Pers. assigned to 1st preference (%)
From 1st level to 2nd level	501	24	489	23	497	14	−0.80	−41.67
From 2nd level to 3rd level	825	32	803	29	771	12	−6.55	−62.50
From 3rd level to 4th level	534	31	510	27	460	17	−13.86	−45.16
Total	1860	87	1802	79	1728	43	−7.10	−50.57

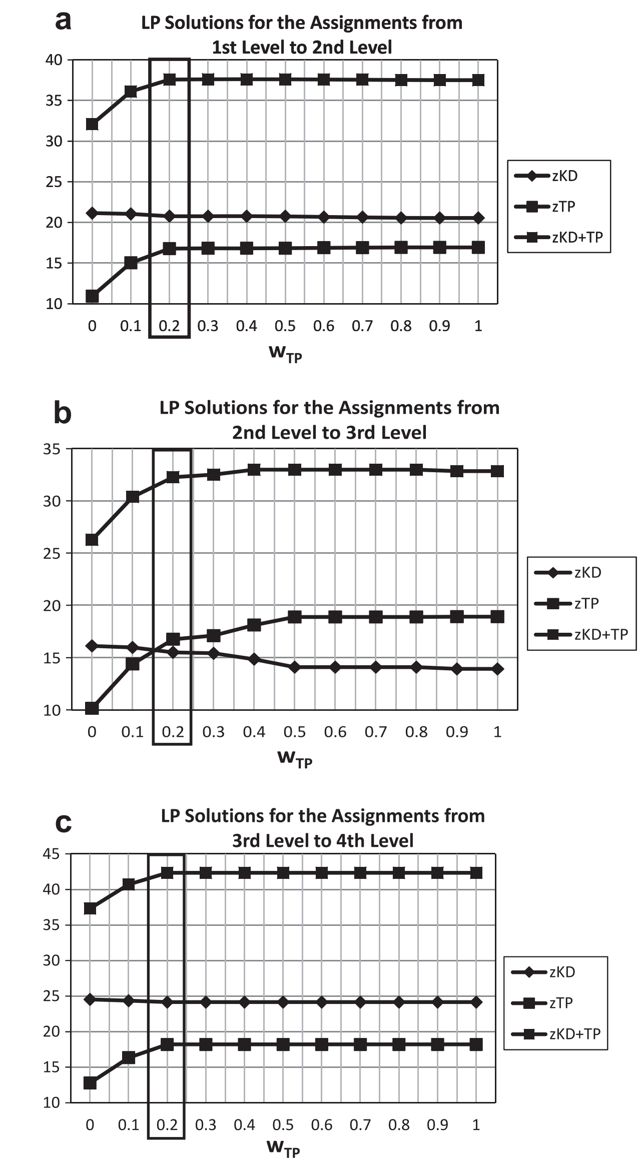

Fig. 7. (a) z_{KD}, z_{TP} and z_{KD+TP} values for the assignments from 1st level to 2nd level, **(b)** z_{KD}, z_{TP} and z_{KD+TP} values for the assignments from 2nd level to 3rd level, **(c)** z_{KD}, z_{TP} and z_{KD+TP} values for the assignments from 3rd level to 4th level.

that personnel *i* can be assigned and p_j the set of personnel that can be assigned to position *j*.

We first ran the LP model with the following weight combinations: $w_{KD} = 1$, $w_{TP} = 0$. The results and their comparison with two-sided matching are shown in Table 11; the assignments made by the LP model resulted in 7.1% less training need. On the other hand, a dramatic decrease of 50.6% was observed in the number of people assigned to their first preference. This decrease stems from the choice of weight combination (i.e. $w_{KD} = 1$, $w_{TP} = 0$).

Later, we solved the LP model for various weight combinations $((w_{KD}, w_{TP}) = (1.0; 0.0), (0.9, 0.1), (0.8; 0.2), (0.7, 0.3), (0.6; 0.4), (0.5; 0.5), (0.4; 0.6), (0.3, 0.7), (0.2; 0.8), (0.1; 0.9)$ and $(0.0; 1.0))$ to determine the combination that would best satisfy personnel's preferences and person-to-position compatibility. We present the objective function values z_{KD}, z_{TP}, z_{KD+TP} and trade-off curves of these operations in Fig. 7.

The values in the boxes in Fig. 7 belong to a combination of weights where the curve of function z_{KD+TP} loses its straight inclination. These values are called Pareto optimal (Miettinen, 1999), and for a rational decision maker these combinations mean that we should not allocate a weight for personnel preferences (TP) below 20%. In other words, there is no need to allocate a weight of more than 80% for person-to-position compatibility (KD). We ran the results of the LP model with these Pareto optimal values and show the two results in Table 12.

Compared to the two-sided matching approach, the assignments made by the proposed LP model (with Pareto optimal weight combinations $w_{KD} = 0.8$, $w_{TP} = 0.2$) resulted in a 4.25% lower training need. We also achieved a 4.60% increase in the number of personnel assigned to their first preference.

5. Results

In this study we propose a chain of methodologies (CECPM) to decrease training costs and increase the level of specialization in hierarchical organizations. Our CECPM investigates previous period before the course-planning to determine how training needs evolve, and considers HRM's job analysis/description, career planning and assignment functions to decrease the effects of assignments on training needs. Our CECPM is implemented, as shown in Fig. 8, in the following steps of the HRM process:

- In the job analysis/description step, the amount of training needed for a personnel assigned to a position is defined in measurable units by our mission description matrix. This matrix

Table 12
Comparison of assignments.

Assignments	Method								Difference (1,4)	
	1. Two-Sided Matching (AHP)		2. Two-Sided Matching (Career Matrix)		3. Linear Programming (wTP=0)		4. Linear Programming (Pareto)			
	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit)	# Of Pers. assigned to 1st preference	Training need (Unit) (%)	# Of Pers. assigned to 1st preference (%)
From 1st level to 2nd level	501	24	489	23	497	14	484	28	−3.39	16.67
From 2nd level to 3rd level	825	32	803	29	771	12	793	32	−3.88	0
From 3rd level to 4th level	534	31	510	27	460	17	504	31	−5.62	0
Total	1860	87	1802	79	1728	43	1781	91	−4.25	4.60

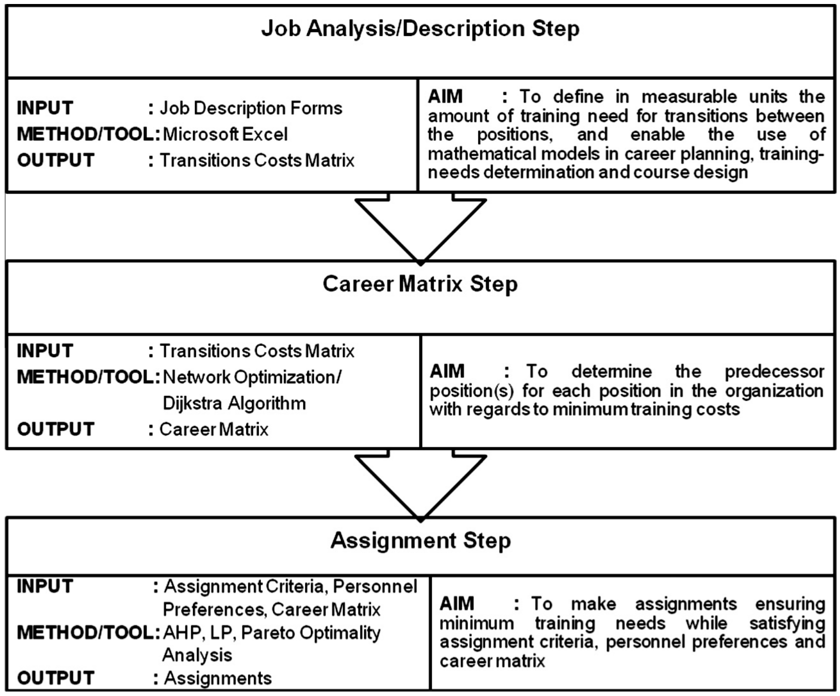

Fig. 8. Functioning of Cost-Effective Course Planning Model (CECPM).

transforms the traditional job description forms into a groundwork that makes possible the use of mathematical models in career planning, training-needs determination and course design, helps generating the transition costs matrix as well.

- In the career matrix step, for each position in the organization the predecessor position(s) with regards to minimum training costs are determined using our network-flow model (shortest-path optimization). The shortest path problem is formed by assuming the positions in an organization are nodes, all the possible transitions between the positions are edges, and the costs of training are distances between the nodes. The problem is solved by using Dijkstra Algorithm. This provides that: (1) career paths are scientific documents depending on measurable data rather than intuitive information (2) job analysis/description data is usable in career planning, and (3) career paths can be used as measurable criteria in assignment. Because the career plan in our study aims for the least training needed, the way it is constructed also helps improve employee specialization. This step uses mission description matrix as an input and generates career matrix as an output.
- In the assignment step, we propose a decision support system composed of AHP, LP and Pareto optimality analysis. The predecessor position(s) derived according to minimum training costs are integrated in the assignment model as a criterion such as evaluation scores, health status, foreign language status etc. by using AHP. Our proposed system ensures minimum training needs while satisfying person-to-position compatibility and personnel's preferences. It also helps to control and determine the weights to be allocated to performance criteria. As far as the proposed LP model is concerned the model can be easily modified by inserting additional constraints if asymmetry (in terms of number of vacant positions and personnel) or force shaping issues is inevitable.

We selected one of the state of the art studies in the literature in order to test the efficiency of CECPM, and we compared our CECPM against the AHP and two-sided matching model proposed by Korkmaz et al. (2008) under a hypothetical scenario. Compared to model of Korkmaz et al. (2008), which has proven its superiority in manually conducted assignment processes, our CECPM achieved a 4.25% lower training need and a 4.60% increase in the number of personnel assigned to their first preference. This 4.25% decrease means a saving of approximately 1.1 million $ for a military organization with about 90,000 personnel. This saving, while substantial, only includes travel allowance and accommodation, i.e. it does not include the expenses that the training center spends for training activities and the indirect costs of having a personnel away from work. In summary, we achieved reduced training needs, and increased morale and motivation (given the high number of personnel's preferences matched) by using;

- The previous duty criterion whose priorities derived from career matrix.
- Optimization instead of two-sided matching.
- Pareto optimality to find the weights to be allocated for person-to-position compatibility and personnel's preferences.

6. Conclusion and implications

Our CECPM focuses on hierarchical organizations where job rotations and corresponding training needs take place in big numbers. It is not tested in any real life environment. Implementing it requires various modifications and attentive testing. Although its expected utility is believed to become visible in government agencies, the concept of person-to-position compatibility is very applicable in private service and/or manufacturing organizations as well. Through some modification our CECPM can be used to assign the right employees to the right industrial tasks, machines, or workstations. Due to its capability to consider two objectives, tasks can be assigned to employees based on the skill level and physical capability not only to achieve high productivity but also to enhance the workers' career needs. Most organizations have a policy to reassign their employees or allow them to transfer to other positions at some given intervals. Frequently, the reassignments and/or transfers result in inevitable training expenses. When there are many employees (and jobs) involved, it is rare that the outcomes of decisions of human decision makers are optimal. Considering both objectives concurrently while satisfying the need for minimum training expenses is a difficult task to perform, especially for human decision makers. Our CECPM can be applied in determining an optimal employee-job assignment solution. A mathematical programming approach, our CECPM, is thus a practical tool for any private service and/or manufacturing organization to generate optimal employee-job assignment solutions with minimum training needs.

Our CECPM includes the following extensions for future work:

- When we constructed the job description matrix in Section 4.1, we assumed the quantity of training need for an employee in a new position to be "1" for simplicity, because differences in needs (which can vary depending on competencies) do not affect the outcomes of this study. The exact values for quantities of training needs, however, should be computed when constructing a job description matrix for a real-world problem. Developing a method to calculate the exact training needs for each possible replacement in an organization could be further explored.
- In the assignment model, we assume that the personnel prefer particular positions. In some real-world problems, personnel may prefer particular locations (i.e. cities) where there are different types of positions. With those problems, the scope of the assignment model could be extended to formulate such an objective.
- The theory of our CECPM provides valuable contributions to ensure cost-effective course plans for hierarchical organizations and the computer-based support for the theoretical frame and the application phases increases the consistency of the proposed system in practice.

References

Armacost, A. P., & Lowe, J. K. (2005). Decision support for the career field selection process at the US Air Force Academy. *European Journal of Operational Research, 160*, 839–850.

Barron, G., & Vardy, F. (2004). The internal job market of the IMF's economist program. In *IMF Working Paper*, IMF Institute, pp. 6–12.

Bhargava, H. K., & Snoap, K. J. (2003). Improving recruit distribution decisions in the US Marine Corps. *Decision Support Systems, 36*, 19–30.

Bhushan, N., & Kanwal, R. (2004). *Strategic decision making: Applying the analytic hierarchy process*. London: Springer-Verlag.

Campion, M. A., Cheraskin, L., & Stevens, M. J. (1994). Career-related antecedents and outcomes of job rotation. *Academy of Management Journal, 37*(6), 1518–1542.

Cherkassky, B.V., Goldberg, A. V., & Radzik, T. (1993). *Shortest paths algorithms: Theory and experimental evaluation*. Technical report 93–1480, Computer Science Department, Stanford University.

Eiselt, H. A., & Sandblom, C.-L. (2007). *Linear programming and its applications*. Berlin Heidelberg: Springer-Verlag, pp. 337–339.

Expert Choice (2009). 1501 Lee Highway, Suite 302, Arlington, VA 22209. <http://www.expertchoice.com>.

Hamdy, A. T. (2007). *Operations research: An introduction* (8th ed.). Pearson Education, Inc., pp. 248.

Holder, A. (2005). Navy personnel planning and the optimal partition. *Operations Research, 53*(1), 77–89.

Jaturanonda, C., & Nanthavanij, S. (2005). Optimizing employee-job assignment based on competency-based and preference-based person-job fit. *International Journal of Industrial Engineering – Theory, Applications and Practice, 12*(4), 365–377.

Jaturanonda, C., Nanthavanij, S., & Chongphaisal, P. (2006). A survey study on weights of decision criteria for job rotation in Thailand: Comparison between public and private sectors. *International Journal of Human Resource Management, 17*, 1834–1851.

Jaturanonda, C., & Nanthavanij, S. (2011). Analytic-based decision analysis tool for employee-job assignments based on competency and job preference. *International Journal of Industrial Engineering, 18*(2), 58–70.

Koh, G.K.S. (2002). *A redesign of the Navy's enlisted personnel distribution process*. Master's Thesis, Monterey, CA: Naval Postgraduate School. Unpublished manuscript.

Korkmaz, İ., Gökçen, H., & Çetinyokuş, T. (2008). An analytic hierarchy process and two-sided matching based decision support system for military personnel assignment. *Information Sciences, 178*, 2915–2927.

Miettinen, K. M. (1999). *Nonlinear multiobjective optimization*. USA: Kluwe Academic Publishers.

Peters, M. L., & Zelewski, S. (2007). Assignment of employees to workplaces under consideration of employee competences and preferences. *Management Research News, 30*(2), 84–99.

Pöyhönen, M., & Hämäläinen, R. P. (2001). On the convergence of multiattribute weighting methods. *European Journal of Operational Research, 129*, 569–585.

Prien, E. P., Goodstein, L. D., Goodstein, J., & Gamble, L. G. (2009). *A practical guide to job analysis*. John Wiley & Sons, Inc.

Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill.

Saaty, T. L. (2000). *Fundamentals of decision making and priority theory*. Pittsburgh, Pennsylvania: RWS Publications.

Saaty, T. L. (2008). *Decision making for leaders: The analytic hierarchy process for decisions in a complex world*. Pittsburgh, Pennsylvania: RWS Publications.

Tan, S. J., & Yeong, C. M. (2001). *Designing economics experiments to demonstrate the advantages of an electronic employment market in a large military organization*. Master's Thesis, Monterey, CA: Naval Postgraduate School. Unpublished manuscript.

Toloie-Eshlaghy, A., Homayonfar, M., Aghaziarati, M., & Arbabiun, P. (2011). A subjective weighting method based on group decision making for ranking and measuring criteria values. *Australian Journal of Basic and Applied Sciences, 5*(12), 2034–2040.

Wasmund, T. (2001). *Analysis of the US Army assignment process: Improving effectiveness and efficiency*. Master's Thesis, Monterey, CA: Naval Postgraduate School. Unpublished manuscript.

Zadeh, M. (1963). Optimality and non-scalar-valued performance criteria. *IEEE Transactions on Automatic Control, AC, 8*, 59–60.