International Journal of Economics & Strategic
Management of Business Process (ESMB)
Vol.11 pp 54-58

Assignment problem under skills and preferences constraints: A case study

Lamjed Souidi #1, Marwa Khalfalli #2 and Younes Boujelbene #3

#University of Economics and Management of Sfax, Tunisia
Road Airport Km4 Sfax, Tunisia

[1]lamjed44@hotmail.com
2 marwakhalfalli2013@gmail.com
3 younes.boujelbene@gmail.com

***Abstract*—In this work, we present an assignment problem of human resources, taking into account their skills and their preferences. Composite three stages (assessment of competences, modeling of assignment problem, resolution), it constitutes a system effective assignment aimed at better matching the achievements of an agent with the requirements of a task and also the satisfaction of the agents' preferences. To solve it, an exact method method was developed and tested at a central university in Tunisia.**

***Keywords*—Assignment problem, Competences, Preferences**

I. INTRODUCTION

Recognition of the important role of human resources in issues related to the conduct of different processes is justified more by a variety of research that has focused on the combined integration of skills and preferences, either to the integration of one two human characteristics (skills or preferences), allocation problems, planning or scheduling. This emancipation has engendered a change in the formulations of these problems. Moreover, a better identification of skills and a distinguished presentation of preferences constitute two conditions for more precise modeling of the constraints taking into account these resources in their workplace.

In a highly competitive environment, the company must be more flexible, responsive and innovative. Conscious of these imperatives, it grants a particular attention to the involvement of human capital as a distinctive element of performance. Indeed, the accession of human capital through the mobilization of its skills is an effective lever for achieving the objectives and improve business performance. Next to this unavoidable concern for the management of skills, business leaders find themselves placing an interest growing to meet the needs of those resources that allows for a clear improvement in the quality of their yield and therefore, induced performance.

We hope through this work to provide leaders with companies a concrete tool for decision support they would deploy to address one of the issues related to the conduct of administrative processes, such as the problem allocation of human resources while taking into account their skills and preferences.

II. LITERATURE REVIEW

In the health field, Aickelin and Dowsland [1] presented a time schedule for hospital service by assigning assignments to different nurses. To do this, the authors work to distribute evenly the unwanted vacations and to find the answer to the needs of each session in term of number of nurses to ensure a better assignment whose objective is to minimize the cost of preference which translates the usefulness of a schedule for a nurse, the lower the schedule is in terms of satisfaction of the nurse's preferences. This problem is solved by a genetic algorithm by assigning a permutation by replacing a low-grade nurse with highly qualified nurse, but not the other way around.

Thus, Mkaouar [2] presented an approach based on the combination of the advantages of the bee algorithm and the immune system for the assignment of engineers according to skills and preferences in a company in the telecommunications sector. They aimed to minimize the cost of assignment while minimizing the gap between skill levels acquired by the resources and required by the tasks and by best respecting the preferences. On the other hand differentiate between resources according to their grades, in [3][4] the authors were interested in proposing assignments based on required needs detailed in terms of competency criteria. Indeed, the study of the impact of skills and preferences on the company's performance is neglected. Thus, Wei et al. [5] presented a two-stage stochastic model for a problem of home-based assignment of health care structures. They sought to assign nurses to patients over a planning horizon while considering the skills and abilities of nurses and taking into account the randomness of the time required. The goal is to find the balance of nurses' workloads.

Peters and Zelewski [3] presented the assignment problem as a program by goals to search a best compromise between the three objectives defined in terms of skills and preferences. For that, a prior identification of some of the variables of the

ISSN 2356-5608

problem (degrees of importance of skills by report to each post, the skills preferences required, the preferences of candidates in relation to skills to be mobilized) by the AHP method.

Sabar [6] tackled the scheduling problem and real-time staffing. It proposed a mathematical model of the dynamic assignment problem of employees on an assembly line with the consideration of preferences, skills and inter-station employee movements. Although skills and preferences have been well defined in this work, the authors have often neglected the impact of either of these two human aspects on performance administrative. Such a lock has led us to explore the studies who have taken a separate interest in the problems appropriations and taking into account preferences.

A diversity of significant works interested mainly to resource allocation issues human resources with consideration of skills. Some consider the difference between operators as a factor having a direct impact on operational performance. Thus, as long as the under-privileged actors pass generally longer than the competent actors.

Bennour and Crestani [7] proposed an approach to quantify the impact of the individual dimensions (knowledge, know-how and know-how be) and collective (inter-business and intra-business) skills of human resources in the estimation of modulation rate of the nominal performance of different trades involved in carrying out the activities of a process. In other studies, the authors have shown that actual duration of a task can vary linearly depending on the rate of competence (Marmier [8]). Gruat et al. [9] considered the duration of a task according to productivity of the resource that will run.

Unlike the last two studies, Valls and al., [10] assumed that the execution time of a task varies by a certain percentage predefined according to the level expertise of the resource (senior, standard, junior) that is affected.

More recently, Hlaoittinun [11] and, Gonsalves and Itoh [12] proposed an approach to correct the duration of realization of a task based on a degree of similarity that allows to estimate the proximity between the required skill levels and acquired skills.

So, the execution time can be set under the form of a linear function of a corrective coefficient which can vary linearly [11] or exponentially [12] according to the degree of similarity between required and acquired levels.

III. Proposed approach

Moreover, a better identification of skills and a distinguished presentation of preferences constitute two conditions for more precise modeling of the constraints taking into account these resources in their workplace.

We model the problem as a linear program. We applied our approach in the Central University in Tunisia for the allocation of three teachers to the four modules.

1) Identification and assessment of skills: To identify the required skills in this problem, we refer to the entity-relationship proposed by Harzallah and Vernadat [13]. The adapted topology of competence resources to the different aspects is presented in table1.

TABLE I
TYPOLOGY OF RESOURCES WITHIN THE JURISDICTION

(Harzallah and Vernadat [13])

	Category of competence		
	Regular	**Bold**	**Italic**
Resources Skills	Theoretical Knowledge (TK)	Procedural Know-How (PK - H)	Relational (R)
	Knowledge of the Existing (KE)	Empirical Know-How (EK - H)	Cognitive Capacity (CC)

According to the topology described in table 1, we determine the matrix (resources of competence * task).

TABLE 2
MATRIX (RESOURCES OF COMPETENCE * MODULE)

Cat. of competences	**Module 1 (M1)**	**Module 1 (M2)**	**Module 1 (M3)**	**Module 1 (M4)**
TK	Computer tools	Production management	Operational research	Statistics
KE	Workplace safety standards	Workplace safety standards	Workplace safety standards	Workplace safety standards
KP	Principles database management	Performance indicators	Optimization problems	Analyze of difficult problems
PK – H	Using Access, SQL	Using computer-assisted management	Using Ceplex	Using SPSS
EK – H	Creation of new work for better learning situations	Implementation of storage process	Creation of new work for better learning situations	Creation of new work for better learning situations

ISSN 2356-5608

R	Know how to communicate with the students	Know how to communicate with the students	Know how to communicate with the students	Know how to communicate with the students
CC	Conflict management	Conflict management	Conflict Management	Conflict Management
B	Curiosity about the student behavior	Curiosity about the student behavior	Curiosity about the student behavior	Curiosity about the student behavior

2) Mathematical model

We recall that a classic assignment problem allows to assign n individuals to m tasks (with $n > m$). For each partial assignment of individual *i* to task *j*, there is a cost. As part of this work, our goal principal is to find the best match between these two subsets with a minimum total cost, trying to minimize the gap between skills required and acquired and to satisfy the preferences of the operators.

The parameters of our model are defined as follows:

P_{ij} : Execution time of job *j* by human resource *i*

CC_{ij} : Proximity coefficient between task *j* and human resource *i*

e_i : Hourly cost of each human resource *i*

S_{ij} : Penalty cost due to dissatisfaction with human resource preference *i* for task *j*

b_{ij} : Cardinality corresponding to each linguistic variable

$CT^{\max}$: Total workload of the resource *i*

$P_{avr,j}$: Average execution time of task *j*

To model the assignment of resource *i* to task *j*, we used a binary variable X_{ij} defined as follows:

$$X_{ij} = \begin{cases} 1 \text{ If resource } i \text{ is assigned to task } j \\ 0 \text{ otherwise} \end{cases}$$

Objective function

$$\text{Min} \sum_i \sum_j e_i (2^{ref - b_{ij}} - 1) X_{ij}$$

Constraints include:

1. Each task can only be performed by a single resource

$$\sum_i X_{ij} = 1, \quad 1 \le j \le m \qquad (1)$$

2. A capacity constraint, it shows that a load of each resource does not exceed the total workload

$$\sum_i P_{ij} . X_{ij} \le CT^{\max}, \quad 1 \le i \le n \qquad (2)$$

A resource i can be assigned to a maximum of two tasks

$$\sum_i X_{ij} \le 2, \quad 1 \le i \le n \qquad (3)$$

The necessary data in this proposed model: the average execution time ($P_{avr,j}$) as well as the maximum workload ($CT^{\max}$) which corresponds to the number of hours available for each candidate, cost per working hour and preferences of each candidate. These data are summarized in the following table:

TABLE 3

THE AVERAGE EXECUTION TIME OF EACH TASK ($P_{avr,j}$), THE COST PER WORKING HOUR (e_i), THE NUMBER OF AVAILABLE HOURS AND, THE DEGREES OF PREFERENCES OF EACH CANDIDATE

	$P_{avr,j}$	**C1**	**C2**	**C3**
e_i	–	17	17	17
$CT^{\max}$	–	40	40	40
T1 (M1)	20	VH	M	L
T2(M2)	15	L	H	H
T3(M3)	20	L	M	VH
T4(M4)	20	VH	M	H

With:
"L": low preference level.
"M": average preference level.
"H": high preference level.
"VH": very high preference level.

Thus the following table shows the values of the assignment costs of the candidates for the various tasks.

ISSN 2356-5608

TABLE 4
COST OF ASSIGNMENT FOR EACH CANDIDATE I AND FOR EACH

TASK J

	C1	**C2**	**C3**
T1	304.81	478.38	694.28
T2	487.9	345.95	396.78
T3	648.21	393.21	365.63
T4	394.23	466.14	338.81

Using the CPLEX software, the following assignment results are obtained.

TABLE 5
OPTIMAL ALLOCATION SOLUTION

Candidates	**Task**	CC_{ij}	**Preference**
C1	T1	0.74	VH
C2	T2	O.29	H
C2	T3	0.89	M
C3	T4	0.74	H

3) Experiments result discussion

The result shows that the obtained assignment represents a good compromise between the satisfaction of the candidates' preferences and the high levels of competence

- At the competency level

All candidates are allocated to tasks with proximity coefficients greater than 0.7 only candidate C2, the latter is assigned to task T2 with a proximity coefficient less than 0.5.

It represents a deviation of 54% from the maximum proximity coefficient for carrying out this task.

This assignment can be explained by the multicriteria nature of the model which seeks to find a compromise between several objectives: minimizing the cost of assignment, minimizing the gap between required and acquired levels and satisfying preferences. The latter represents an allocation cost higher than that of the candidate C3. Minimizing the gap between required and acquired levels and satisfying preferences

- At the level of satisfaction of preferences

The tasks T1, T2 and T4 are assigned to candidates with high and very high preference levels. Only task T3 is assigned to candidate C2 having an average preference level, the latter represents an allocation cost higher than that of the candidate having the high preference level. There will be an overshoot of the maximum workload for performing this task.

- Impact of skills and preferences on the assignment cost

The following table shows the percentage of the execution cost and the penalty cost relative to the allocation cost for the optimal allocation result.

TABLE 6
PERCENTAGE OF EXECUTION COSTS AND PENALTY COST

RELATIVE TO ASSIGNMENT COSTS

		% of execution cost	**% of penalty cost**
T1	**C1**	94.4%	5.6%
T2	**C2**	85.2%	14.8%
T3	**C3**	69.7%	30.3%
T4	**C4**	85%	15%

We note that the cost of execution represents a significant percentage of the cost of allocation in relation to the cost of penalties for the different tasks. From these results, it can be concluded that the interest of respecting the candidates' preferences constitute a strategy for reducing the cost of the assignment. Thus, the impact of satisfying candidates' preferences on lowering the assignment cost is better than the impact of the best match between acquired and required competency levels.

VI. CONCLUSIONS

In this paper, we present an assignment problem integrating more realistic constraints. The generated solutions offer a good allocation of human resources according to their skills and preferences while minimizing the cost of assignment. Our approach allows an improvement in the company performance.

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ISSN 2356-5608