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Decision model for allocating human resources in information system projects

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Abstract

Human resource allocation (HRA) can be viewed as core processes of the project management of information systems. Both in organizations, the business of which is to provide solutions for Information Systems, as in units of companies that work with Information Systems (IS), there are frequent demands for human resources to be allocated to IS projects. However, this is not a simple task and becomes more complex as the numbers of projects and professionals, including the range of expertise required, increase. This paper presents a methodology, based on dynamic programming, to assign human resources to software development projects. The methodology takes into account the complexity of each project and the existing capabilities of staff and the skills required for the project. A simulation is used to demonstrate the decision model.

Keywords: Human resource allocation; Dynamic programming; Project management

1. Introduction

Developing high-quality products continues to be a major struggle for software companies to maintain and expand while major contributions to the outcome of software projects depend on decisions taken on the assignment of personnel (Otero et al., 2008). People are critical to the issue of software development and an important part of human resource management is assigning people to development roles (Acuña et al., 2006). This process is not just crucial for generating efficient teams, but it is of strategic importance in all software organizations and can also help them develop a competitive advantage and systematic long term competences (Huemann et al., 2007).

According to Otero et al. (2008), signing-off a reliable software product within its expected deadline is one of the greatest problems for software development organizations. They claim the major cause for this delay is the time required by professionals to acquire specific skills to undertake tasks and yet not meeting a time schedule can result in financial losses to the organization (Laslo and Goldberg, 2008). In the same way, Murch (2000) points out difficulties in software development projects, such as judging how best to allocate human resources. Statistically, most software development projects fail because they have not received enough attention from project managers with regard to their ensuring human resources were appropriately allocated to them. Therefore an expected benefit from improving the processes of resource allocation is to decrease the duration of certain tasks, which will enable companies to become more productive.

Despite all the research and advances in the field, managing software personnel remains a very complicated endeavor. This is due to the fact that people play a fundamental role in software projects, and they determine the quality and productivity of a project (Chan et al., 2008). So, staffing a project properly is very important. However, this is not a simple task, because there are many different possible staff combinations and many factors, usually conflicting ones, to ponder (such as time, cost, quality, and so forth). Therefore, to manage the selection and allocation of staff without some kind of help can be very difficult and can lead

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the manager to forming a team which is not the best for a given situation.

This paper proposes a framework based on dynamic programming with a methodology that determines the fit between the complete set of skills available from a candidate member of a project team and the skills required for that project so as to assist the process of allocating human resources in IS projects. This overcomes some difficulties related to judging how best to allocate human resources. One of them is solved by Otero et al. (2008), when available resources do not possess the complete set of skills required for task. Therefore, this study on how to optimize (minimize) the time required to complete a project points out that assessing how many and which professionals, from the total available in company, should be allocated to each project is essential, when preparing to set up a process to allocate human resources that is adequate.

The first part of the paper reports on a review of the aspects of human resource allocation in software development projects, and explains how the articles cited were applied in other studies. The second part describes the methodological process followed in this study and gives an illustration of how the model can be applied, and thereafter some results from this illustrative example are presented. The final part of the paper discusses some limitations of this methodology and ends with some conclusions and suggestions for further research in this area.

2. Related studies

Human resource management practices are critical for organizational success (Zwikael and Unger-Aviram, 2010), since the cost of human resources is usually the largest one in a software project. Therefore, many approaches have been proposed in the literature to support how best to staff software projects, using distinct techniques, such as simulation, genetic algorithms, fuzzy theory (Barreto et al., 2008; Daher and Almeida, 2010; Kang et al., 2011; Korhonen and Syrjänen, 2004; Mota et al., 2009; Otero et al., 2008), in order to overcome some difficulties that forces the decision maker to assign resources subjectively to tasks based only on a process that is nonsystematic.

Barreto et al. (2008) present an optimization-based approach to support staffing a software project, solved as a constraint satisfaction problem. Their approach takes into account the characteristics of the activities of the project, the available human resources, and the constraints established by the software development organization. However, it does not consider differences in productivity levels according to the characteristics of different modules.

Kang et al. (2011) propose a constraint-based allocation of human resources in software projects by identifying individual-level and team-level constraints based on the literature and interviews with experts. Their approach optimizes the scheduling of human resource allocations, using accelerated simulated annealing (ASA) and provides a guideline to estimate productivity by using the existing COCOMO II effort estimation model. However, as the number of constraints increases, this approach becomes difficult to be implemented. Besides, this paper only considers personnel factors, related do COCOMO II. By the other side, our proposed approach considers others, as: product, platform and project factors.

Otero et al. (2008) presented a methodology to assign staff to tasks for which someone with a set of first-class skills is not available. This methodology, called Best-Fitted Resource (BFR), is a systematic approach to determining the fit between a candidate's set of skills and the skills required for the tasks, and incorporates relationship-ability tables to describe how prior knowledge in various skills contributes to the learning of other skills. However, this approach does not take into account the characteristics of the project.

According to Acuña et al. (2006), assigning people to roles by matching their personal capabilities is a process that characterizes individuals. In other words, it is a process that identifies their personal capabilities, defines the roles and the capabilities they require and matches individuals to the roles they are best suited for. However, this study does not take into account the characteristics of the software project.

Another important study was conducted by Tsai et al. (2003). In this study, they proposed an efficient and integrated computational method, based on designing experiments to resolve the problem of selecting resources using the Critical Resource Diagram (CRD). This is because it focuses on resource scheduling rather than activity scheduling to represent human resource work flow and the precedence of tasks. Secondly, it uses Taguchi's parameter, because this optimizes the selection of appropriate human resources for tasks under dynamic and stochastic conditions. In this approach, human resources are identified as controllable factors, while the tasks, which are generally unpredictable, are considered as uncontrollable ones. Tsai et al. (2003) also use the average of the number of software lines of code written per day to estimate the skill levels needed by human resources.

From the literature reviewed, it is clear that a key issue in software development is to allocate human resources to the daily activities and projects needed by the organization to achieve its stated missions. Therefore, allocating appropriate people to software development is a key issue, and the human dimension can be even more important than the technical one (Acuña et al., 2002).

Consequently, the methodology proposed in this paper incorporates not only matters related to the project itself, but also to the professionals who will implement it.

3. An approach to structuring a model for allocating professionals to IS projects

This section puts forward a model that aims to optimize the allocation of human resources in IS Projects based on the Problem of Dynamic Programming—Effort Distribution Model. Furthermore, this paper includes procedures for estimating the length of a project, the efficiency of the professional and the time required to carry out the project when there is a given number of professionals who have the profiles specified.

3.1. Characterizing the problem

Many improvements have been identified with the objective of maximizing success in IS projects. Yet, much remains to be done to increase the number of successful projects, i.e. for these to be completed on time, within budget, and with the features and quality desired by the client.

According to Korhonen and Syrjänen (2004), one activity to be prioritized is the allocation of human resources to projects. Because this presents a certain degree of complexity, when such allocation is inadequate, this can generate several problems which negatively influence the success of projects.

Several factors may influence the assignment of professionals to IS projects, amongst which are: the number of professionals needed; the number of professionals available; the possibility of a professional exercising more than one function; the possibility of allocating a professional to several projects in parallel; and the possibility of allocating several professionals to various projects (Chan et al., 2008). Similarly, it can happen that during innovative software development projects, the need for new tasks may arise unexpectedly and while project managers do and should make every effort to foresee these, a sudden need for skills in a new task may appear and require an existing or new team member to acquire them.

As stated by Acuña et al. (2006), assembling the project team involves seeing to it that the necessary human resources are allocated to the project and identifying the functions and tasks to be carried out during the project and the people that should be designated to work on it, in accordance with how their respective roles and responsibilities are defined. This structuring is supported by the Matrix of Responsibilities, which relates the people (who) to the work (what).

In the activity of allocating human resources to IS projects in organizations, some decisions need to be taken and are strongly linked to the project manager's leadership function (Raiden et al., 2004). Among such decisions, the manager must decide whom to allocate to each project. Project Managers should ensure that the project appropriately receives staff with the required skills at the right time. To do so, there is a need to find the professionals in the organization who have the profile needed and are available from the moment that the project needs them. Moreover, there is also the need to allocate, in the best possible way, professionals to projects which are already underway and either require more staff with the same skills or one or more team members who have the skills required for the phase of the project that is about to begin. This task is not simple, because usually there are a number of different possible allocations. Thus, it is in the manager's interest that he/she should be supported in this complex activity, so as to optimize the result, whether this is by minimizing the time needed to complete the project, by minimizing the cost to achieve this or even by maximizing performance in the development of projects. To sum up, according to Chan et al. (2008), team task skills are a critical factor for software development projects.

In the decision model put forward in this article, consideration is given to the particular situation in which there are a specific number of professionals to be allocated to various projects. In this case, it is assumed the professionals have different skills. What is wanted is that the allocation minimizes the total time needed to carry out all projects. In this case, the complexity of the individual projects is taken into account in order to assess how many and which professionals, from the total available, should be allocated to each project.

3.2. The dynamic allocation model

This section presents the context and the structure of the problem of allocating human resources to a software development project.

3.2.1. Context of the problem

The context of this issue is set in a software development company that works with multiple projects and needs to allocate teams to projects simultaneously. However, one of the characteristics of this context is that human resources are not shared between different projects in order not to reduce their productivity (Kang et al., 2011).

Moreover, since these teams consist of company employees, staffing costs are not considered, since the cost involved in the allocation of staff is the cost per person/ month.

Therefore, the company's goal is to minimize the total time taken to complete the project by considering the characteristics of each professional in each project.

In practice, the company should plan to meet the demand for new projects by distributing its staff between the new projects, even if this means removing a professional who is working on a project still in progress. The model proposed in this paper allows the company to do so in order to minimize the total execution time of projects, thus freeing its staff to meet new demands.

3.2.2. Problem structure

The proposed dynamic model is based on the classical model of dynamic programming, which is the model for the problem of distribution of effort (Wagner, 1972). In the context of allocating human resources to IS projects, the difficulty about building this model lies in how to assess the complexity of projects objectively. The proposed model (Fig. 1) seeks a better way to distribute staff, while meeting the following restrictions:

a. Several professionals allocated to several projects. The allocation should be defined in accordance with the shortest time to complete the project (based on an estimate of the end-date)
b. At least one professional should be allocated to each project. It cannot happen that a project does not have a fully qualified staff member allocated to it.
c. All the professionals cannot be allocated to a single project. This restriction is imposed due to the fact that, in practice, all projects should be implemented and that no project should be interrupted/ postponed so as to complete others.

It is assumed there is a company that is undertaking n projects (P1, P2… Pn). The company has an X number of professionals, and is interested in determining how many professionals should be allocated to each project so as to minimize the total time needed to carry out all of these *n* projects. That is, for each project, there is a need to know how long the tasks will take if a specific number of professionals is allocated to them. As mentioned above, and because there is a desire to minimize the total time

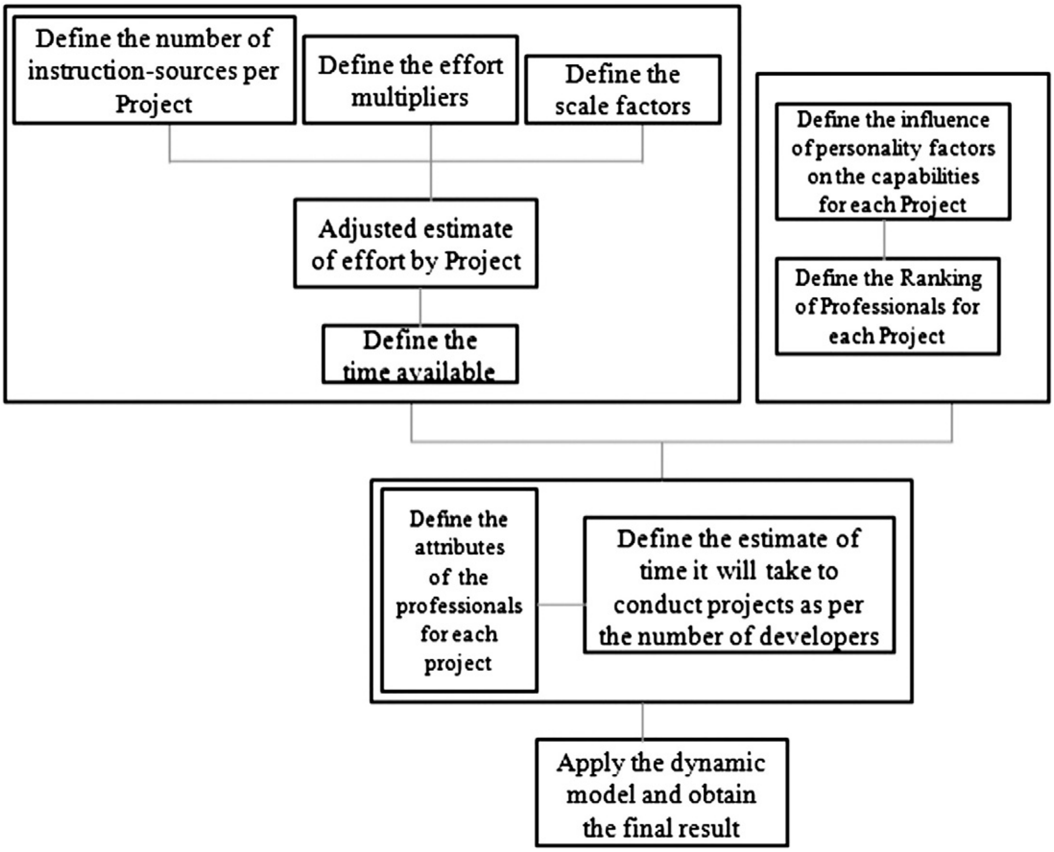

Fig. 1. The proposed model.

needed to carry out all ongoing projects, not all professionals should be allocated to the same project.

In fact, this problem of allocating professionals, as described, is not a problem of dynamic programming, but it can be modeled as if it were, since it is possible to define all the elements of a problem of dynamic programming, which are:

- Stages of the problem—Decision taken on allocating professionals to projects 1, 2 …n.
- States - s_0, s_1, s_2… s_n, refer to the number of professionals not yet allocated to projects. Initially, s_0, there are 10 professionals not yet allocated. During the process of allocating, the number of professional is reducing until the project n has its professionals allocated, s_n.
- Decision variables—y_1, y_2… y_j, refer to the number of professionals allocated to each of these projects.
- Objective function and constraints—

$$\text{Min} \sum_{j=1}^{s} R_j\left(y_j\right) \tag{1}$$

$$\text{s/ to} \sum_{j=1}^{s} y_j = n,\ y_j = 0,\ 1,\ 2,\ \ldots \text{ for each j.}$$

In which:

y_j is the number of professionals allocated to Project j
$R_j(y)$ is the time to completion of Project j when $y_j = y$.

and the constraint is related to each project has at least one professional allocated, as commented before in items a, b, c. The mathematical model used to solve this problem is adapted from the problem of the distribution of effort and in this case, the interest is in minimizing the time needed to complete the project. The solution for the resource to solution relationship of this optimization problem is:

$$\begin{aligned} &g_j(n) = \min_y \left[R_j(y) + g_{j-1}(n-y)\right] \\ &\text{for j} = 1, 2, \ldots, \text{s} \\ &g_0(n) \equiv 0 \text{ to j} = 0, \text{n} = 0, 1, \ldots, \text{n} \end{aligned} \tag{2}$$

The predominant factor of this problem is to estimate how long it will take to undertake a project by means of determining how many professionals should be allocated to it. According to Hill et al. (2000), the techniques that have been used to estimate project effort and task duration include expert judgment, analogy, parametric models (COCOMO and Bang are the most used), Function Point Analysis and, recently, neural networks and case based reasoning. In another study, Dillibabu and Krishnaiah (2005) used COCOMO II.2000 to estimate the effort of an embedded system project. The COCOMO II effort estimation model (Bohem et al., 2000) is shown in Eq. (3).

$$PM = A \times Size^E \times \prod_{i=1}^{m} EM_i \tag{3}$$

where, P/M stands for persons/month. The inputs are the Size of software development in KDSI, which stands for thousands of source-instructions delivered, a constant A, an exponent E, that is an aggregation of five scale drivers, described in Table 1, that account for the relative economies or diseconomies of scale encountered for software projects of different sizes, and a number of values, m, called effort multipliers (EM_i), which depends on the model. The latter, as can be seen in Table 2, are classified by product factors, platform factors, personnel factors, and project factors.

The project's scale factors are summed and used to determine a scale exponent E, as per Eq. (4).

$$E = B + 0.01 \times \sum_{j=1}^{5} SF_j \quad (4)$$

In COCOMO II.2000 (Dillibabu and Krishnaiah, 2005) the constants A and B are equal to, respectively, 2.94 and 0.91.

Therefore, knowing that the length of time available is defined as follows:

$$Time\ available = \frac{effort}{number\ of\ professionals}, \quad (5)$$

and substituting the value for effort with the representation of Eq. (3), results in:

$$Time\ available = \frac{A \times Size^E \times \prod_{i=1}^{m} EM_i}{number\ of\ professionals} \quad (6)$$

In order to develop the time available, the values of the scale factors and effort multiplier for each factor are detailed in Tables 3 and 4, below. These weights are already pre-established, according to Bohem et al. (2000). It is important to note that some cells are in grey. This means, for example, that as DATA is determined by calculating the ratio of bytes in the testing database to SLOC in the program (D/P), it is rated as low if D/P is less than 10 and it is very high if it is greater than 1000. Therefore, the decision-maker is responsible for classifying the attributes to his/her respective projects. More details about the scale factors and effort multipliers can be found in Bohem et al. (2000).

After determining the non-adjusted effort and the characteristics of the software, the product of the multipliers by the non-adjusted effort is made, so that the initial estimates are adjusted up or down.

Knowing that human resources technical skills and implementation experience are key factors for project success, the staff member must be allocated and managed judiciously (Tsai et al., 2003). Therefore, one must consider that each professional has his/her own skills for a particular project. The levels of each professional's skills in each project depend directly on their profiles. According to Acuña et al. (2006), the profile of professionals as well as their skills in each project depend on a few capabilities such as: intrapersonal (analysis, decision-making, independence, innovation, critical thinking, persistence and tolerance of stress), organizational (self-organization, risk management, environment knowledge, discipline, and environmental orientation), interpersonal (customer service, negotiation skills, empathy, social skills and teamwork) and management (supportive work, group leadership and planning and organization).

Another important factor is the time that needs to be spent on developing the project. Therefore, there is a system for assessing rhythms, Westinghouse System (Barnes, 1980), which uses four factors to estimate the professional's efficiency. These factors are: ability, effort, conditions and consistency. The system provides a table with numerical values for each factor. Therefore, the time obtained from the estimate of how long each professional should take to complete specified project tasks is normalized by applying the sum of ratings for the four factors, as shown in Table 5 below.

An example of the application of this system is illustrated in the following section.

Table 1
Scale factors.
Adapted from Bohem et al. (2000).

Scale factors
PREC—precedentedness
FLEX—development flexibility
RESL—architecture/risk resolutions
TEAM—team cohesion
PMAT—process maturity

Table 2
Multipliers of effort.
Adapted from Bohem et al. (2000).

Product factors	Platform factors
RELY—required software reliability	TIME—execution time constraint
DATA—data base size	STOR—main storage constraint
CPLX—product complexity	PVOL—platform volatility
RUSE—developed for reusability	
DOCU—documentation match to life-cycle needs	
Personnel factors	**Project factors**
ACAP—analyst capability	TOOL—use of software tools
PCAP—programmer capability	SITE—multisite development
PCON—personnel continuity	SCED—required development schedule
APEX—applications experience	
PLEX—platform experience	
LTEX—language and tool experience	

4. Illustration of application of the model proposed

After the model is built, a simulation is performed. This section will address the issue of allocating human resources to Information System (IS) Projects, and demonstrate an application of the proposed model.

Table 3
Scale factors—weights.
Adapted from Bohem et al. (2000).

Scale factors	Very low	Low	Nominal	High	Very high	Extra high
PREC	6.20	4.96	3.72	2.48	1.24	0.00
FLEX	5.07	4.05	3.04	2.03	1.01	0.00
RESL	7.07	5.65	4.24	2.83	1.41	0.00
TEAM	5.48	4.38	3.29	2.19	1.10	0.00
PMAT	7.80	6.24	4.68	3.12	1.56	0.00

Table 4
Multipliers of effort—weights for each attribute.
Adapted from Bohem et al. (2000).

Attributes	Very low	Low	Nominal	High	Very high	Extra high
RELY	0.82	0.92	1.00	1.10	1.26	
DATA		0.90	1.00	1.14	1.28	
CPLX	0.73	0.87	1.00	1.17	1.34	1.74
RUSE		0.95	1.00	1.07	1.15	1.24
DOCU	0.81	0.91	1.00	1.11	1.23	
TIME			1.00	1.11	1.29	1.63
STOR			1.00	1.05	1.17	1.46
PVOL		0.87	1.00	1.15	1.30	
ACAP	1.42	1.19	1.00	0.85	0.71	
PCAP	1.34	1.15	1.00	0.88	0.76	
PCON	1.29	1.12	1.00	0.90	0.81	
APEX	1.22	1.10	1.00	0.88	0.81	
PLEX	1.19	1.09	1.00	0.91	0.85	
LTEX	1.20	1.09	1.00	0.91	0.84	
TOOL	1.17	1.09	1.00	0.90	0.78	
SITE	1.22	1.09	1.00	0.93	0.86	0.80
SCED	1.43	1.14	1.00	1.00	1.00	

4.1. Presentation of the problem of allocating HR to IS projects

In an entity (institution or function) that develops IS projects, there is, periodically, a demand for allocating professionals to its projects.

The problem is to determine the optimum allocation of software developers to three (3) IS projects that will begin at the same time. The company has 10 professionals available who have different technical skills and are to be allocated among these three projects. There is an *a priori* estimate of the number of instruction-sources to be developed in each project. In this allocation, the ideal is to find a solution that minimizes the length of the three projects, which will be given in terms of the time needed to complete each project per given number of developers.

Table 5
Estimate of performance.
Adapted from Barnes (Barnes, 1980).

Ability			Effort		
+0.15	A1	Super skilled	+0.13	A1	Excessive
+0.13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2		+0.08	B2	
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2		+0.02	C2	
0	D	Medium	0	D	Medium
−0.05	E1	Regular	−0.04	E1	Regular
−0.10	E2		−0.08	E2	
−0.16	F1	Weak	−0.12	F1	Weak
−0.22	F2		−0.17	F2	
Conditions			**Consistency**		
+0.06	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0	D	Medium	0	D	Medium
−0.03	E	Regular	−0.02	E	Regular
−0.07	F	Weak	−0.04	F	Weak

The first step is to establish an average number of instruction-sources for each project, followed by assigning the weights of the scale factors and effort multipliers, for each project. Table 6 below summarizes all these items of information, which were collected from Dillibabu and Krishnaiah (2005).

Given that the characteristics of each project have been obtained, the next step is to calculate the adjusted effort, as per Eqs. (3) and (4). For project 1, according to Table 6, the sum of scale factors is 1.0803 and the product of the multipliers effort is 0.6562. Knowing that the size of the project 1 is 12.58 Kloc, and considering A and B, from Eqs. (3) and (4), respectively equal to 2.94 and 0.91 (COCOMO II.2000), the effort estimate is obtained using Eq. (3), so that it is equal to 29.74 persons/month.

In the same way, the values of project 2 and project 3 are obtained. The results, in persons/month, are presented in Table 7 below.

With respect to the professionals to be allocated, the following table sets out the skills of each employee for each project. In this case, "x" indicates the abilities which the professional currently possesses and "√" indicates the characteristics of the project. Therefore, the capacity required of each professional in each project is judged as being the percentage fit between the capacity the project requires and the capacity that the professional satisfies.

Fig. 2 shows the scores of one professional related to each of the three projects. All 10 professionals are asked to complete this table. When they have done this, a final ranking can be obtained of the 10 professionals with respect to the 3 projects, based on the scores they obtained, as per Table 8.

A problem may occur when a professional is best ranked and allocated to more than one project. In this case, the professional should be the one who has the skills needed to ensure the projects to which he/she will be allocated will be completed in the shortest possible time.

Using this ranking, it is possible to allocate the optimum number of professionals to each project. Therefore, to construct Table 8, the professionals are allocated according to the number of software developers required. For example, if one professional is needed for Project_1, Professional_8 will be allocated. If two professionals are needed, these will be Professional_8 and Professional_10.

Finally, the last step is to calculate the times to completion of the projects in months for a given numbers of developers, using Eq. (6). However, to do so, in accordance with the number of professionals required, the model proposed by Barnes (1980) will be used. This provides a table with numerical values for each factor and the time to completion selected is obtained from the study of this time, as per Eq. (6). This time is normalized by applying the sum of the ratings for the four factors, in order to consider the different skills of each professional.

In this case, the decision maker (DM) should infer the attributes for each professional in each project. For example, Table 9 shows how the DM assigned the attributes of Professional_8 to Project_1:

In this case, the time available for conduct the project is multiplied by 0.29. Therefore, considering that all professionals have a minimum level of experience and, using the following Eq. (7) in each time obtained from Eqs. (6), the DM would be

Table 6
Characteristics of each project.

Project	KLOC	*scale->*	PREC	FLEX	RESL	TEAM	PMAT		
Project_1	12.58		2.48	4.05	5.65	3.29	1.56		
Project_2	13.324		2.48	4.05	2.83	1.10	3.12		
Project_3	5.286		2.48	4.05	5.65	3.29	1.56		
efforts->	RELY	DATA	CPLX	RUSE	DOCU	TIME	STOR	PVOL	
Project_1	0.82	0.90	0.87	1.00	1.00	1.11	1.00	0.87	
Project_2	1.00	0.90	0.87	1.00	1.00	1.11	1.05	0.87	
Project_3	0.82	0.90	0.87	1.00	1.00	1.11	1.00	0.87	
efforts ->	ACAP	PCAP	PCON	APEX	LTEX	PLEX	TOOL	SITE	SCED
Project_1	0.85	0.88	1.29	1.00	1.00	1.09	1.17	0.86	1.00
Project_2	0.71	0.76	1.00	0.88	0.91	1.00	0.90	1.00	1.43
Project_3	0.85	0.88	1.29	1.00	1.00	1.09	1.17	0.86	1.00

able to calculate the respective times to completion, if a given professional were selected. This result is shown below:

$$Time\ available = effort \times \left(1-\left(\sum_{i=1}^{x} C_i\right)\right) \quad (7)$$

where x is the number of professionals selected and C_i is the sum of the values of the attributes for each professional in each project. The estimate of time to completion is shown in Table 10 below.

According to the estimate of time to conduct projects as per the number of developers, we will describe in detail below how we arrived at our results.

5. Results

As mentioned, using the data from Table 10, the readjusted relationship for the problem of dynamic programming is resolved (Eqs. (1) and (2)).

After the simulation model is implemented, the final result for allocation so as to minimize the total time to completion of the three projects is obtained, and this is given in Table 11.

The striking feature of dynamic programming is that the solution is obtained by starting at the end and working backwards to the beginning. This establishes that, in this example, the first 6 professionals in the ranking should be allocated to Project 3. The other four should be allocated to Projects 2 and 1, respectively, so that these projects can be completed in the shortest time.

In this particular case, this situation did not occur, and the result obtained establishes that the minimum time needed to complete all three projects is 44.17 months, since all projects are deemed to start at the same time and are conducted in parallel.

Table 7
Adjusted estimate of the effort by project.

Project	Estimate of effort—COCOMO II.2000(P/M)
Project 1	29.74
Project 2	19.47
Project 3	11.65

6. Discussion

Our results make several contributions to the literature. The first involves putting forward for use and development a framework for allocating human resources to software development projects. We consider a decision making environment in which a project manager controls the management of human resources. We combine dynamic programming with a methodology that determines the fit (i.e., suitability) between the complete set of skills a candidate offers and the skills required for a project.

The second contribution is with regard to the complexity of projects in terms of assessing how many and which professionals, out of the total number available, can be allocated to each project in order to minimize the time required to complete them. It must be borne in mind that the assumption of this study is that estimates of the time software developers require is based on the standard number of lines of code. Some methodologies are found in the literature that support this method of estimating, amongst which the technique of Points by Function (Albrecht and Gaffney, 1983) can be used, taking into account the general characteristics of the application to be developed.

This proposal contributes and objectively supports Project Managers in the difficult task of allocating human resources. The application of the model is relevant when there are several projects with different complexities such that allocating a greater or lesser number of human resources can directly affect the time taken to complete the project. Moreover, this methodology considers that the differences in professionals' skills is extremely relevant when addressing this problem, since human resource allocation in software projects is especially complex because the human characteristics of developers affect the allocation (Kang et al., 2011). Some examples of companies that can use this methodology and/or be used to illustrate its effectiveness are software houses, programming or test pools.

This paper also considers that regardless of the software development methodology used, traditional or agile, the allocation of human resources should be madein the planning stage, such as when designating staff for a project. According to the PMBoK (2004), the designation of staff is part of the mobilization process of the project team. Therefore, this step could be solved using the

Professional 1	Intrapersonal							Organizational					Interpersonal					Management				
	Analysis	Decision-making	Independence	Innovation	Judgment	Tenacity	Stress Tolerant	Self Organization	Risk Management	Environmental Knowledge	Discipline	Environmental Orientation	Customer Service	Negotiation Skills	Empathy	Sociability	Teamwork	Coworker evaluation	Group leadership	Planning and Organization	Capabilites satisfied vs. Required	Match (%)
Project_1	x	x							x								x	x		x	6	
	√	√		√			√		√	√				√		√	√	√	√	√	12	
																						0.5
Project_2	x	x			x			x					x		x			x	x		8	
	√	√	√		√	√		√	√	√			√		√			√	√	√	13	
																						0.615
Project_3		x	x	x							x	x			x				x		7	
	√	√	√	√							√	√		√	√	√			√		10	
																						0.7

Fig. 2. The influence of personality factors on the capabilities for each project.

methodology proposed by the authors. Thus, in order to judge the effectiveness of our approach, the actual duration of the project, or the results from other methods could be considered for benchmark analysis.

Nonetheless, there are some limitations to this research. The first is that, henceforth, developers are basically not shared between teams, and, according to Kang et al. (2011), the sharing of developers between teams lowers efficiency because such developers are under the control of different teams. The second concerns the scope of the project. If the scope changes, this change will influence only the time needed to conduct the project and not the reallocation of human resources, since this has been previously defined. On the other side, if a professional leave the project, the team remains the same, since no project should be interrupted and/or postponed, and this model does not consider sharing human resource.

In the end, both the customer and the organization are interested in the cost of the project. Although this paper does not take into account this measure directly, an estimate of costs in dollars is given by the product of the number of person months times the cost per person month of effort. Therefore, the latter can be calculated indirectly.

Table 8
Ranking of professionals for each project.

Project_1	Project_2	Project_3
Professional_8	Professional_5	Professional_9
Professional_10	Professional_6	Professional_3
Professional_1	Professional_2	Professional_4
Professional_4	Professional_7	Professional_7
Professional_6	Professional_10	Professional_2
Professional_5	Professional_8	Professional_1
Professional_9	Professional_3	Professional_10
Professional_2	Professional_4	Professional_5
Professional_7	Professional_1	Professional_8
Professional_3	Professional_9	Professional_6

Table 9
Attributes of the Professional_8 for Project_1.

Attributes	Code	Value
Ability	B1	+0.11
Effort	A2	+0.12
Conditions	C	+0.02
Consistency	A	+0.04

Table 10
Estimate of time it will take to conduct projects as per the number of developers.

Number of developers	Project 1 (months)	Project 2 (months)	Project 3 (months)
1	21.1154	13.8237	8.2715
2	13.9778	9.1509	5.4755
3	8.6246	5.6463	3.3785
4	5.0558	3.3099	1.9805
5	3.5688	2.3364	1.398
6	2.3792	1.5576	0.932
7	1.487	0.9735	0.5825
8	0.8922	0.5841	0.3495
9	0.5948	0.3894	0.233
10	0.5948	0.3894	0.233

Table 11
Final result of the allocation.

Projects	Number of professionals	professional
Project 1	3	Professionals 8, 10 and 1
Project 2	4	Professionals 5, 6, 2 and 7
Project 3	3	Professionals 9, 3 and 4

7. Conclusions

The mainstream Human Resource Allocation literature still pays greater attention to the management of human resources in routine organization. Therefore, the present paper set out and described an important step in project management, which is the allocation of human resources. The core message that can be taken from this paper is that operational research may be used in the process of human resource allocation, thus aiding the decision maker in this complex activity.

With a view to advancing the search for alternative solutions to the problem of allocating professionals to IS projects, we propose to undertake further research into the model, by inserting other restrictions in order to incorporate the priority aspect of conducting projects, sharing human resources in each project, the partial allocation of human resources, considering changes in the scope influencing the reallocation of the staff, and estimating cost in terms of effort spent on a software product (project). Thus, other variations can be developed for this model. If staffing costs were to be considered, this would imply that the goal of allocating staff is to minimize such costs. Another variation of this model could be to share staff between projects and the purpose of allocation could be to maximize productivity.

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