An integrated model for allocation and leveling of human resources in IT projects

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Received 27 September 2016
Revised 20 May 2017
12 July 2017
Accepted 14 July 2017

Abstract

Purpose – The purpose of this paper is to propose an integrated model for allocation and leveling of human resources in IT projects.
Design/methodology/approach – A single case study was conducted in a large company of IT outsourcing services, which were assessed the management of 14 projects. The survey was conducted through interviews with project managers, and digital files and internal documents of the organization related to these projects.
Findings – In the analysis, it was identified that the critical path is not identified in all projects, and even when this happens, resources are not allocated in the first tasks in that path. A committee controls the allocation of resources with the assessment of skills, but there is no control of all resource constraints.
Research limitations/implications – The main limiting factors for this study are: use of data of one company in the IT industry, making it difficult to generalize the model for other sectors companies; it was noted during interviews that the project managers interviewed do not always know in detail all the company's processes for allocation and resource leveling, due to the large number of processes and different management activities of these professionals.
Practical implications – A model and actions for this implementation was proposed, such as training for the use of the technique of critical path; allocation and leveling done simultaneously; decisions of the management committee based on information of availability, key skills, holidays, days off of human resources; development of a software tool that integrates this information, generating graphical interfaces that are not provided by project management software with the use of an allocation factor.
Social implications – The characteristics of the proposed model, as well as the use of the allocation factor, can help managers to validate their allocation models and leveling of human resources in an integrated manner.
Originality/value – The study explains that the granularity of analysis of resource allocation increases by decomposition of the duration of each activity in fixed time segments. It is suggested to use the mathematical concept of the allocation factor (F_a).

Keywords Project management, Human resources, Resource allocation, Project, Resource leveling
Paper type Case study

1. Introduction

The rapid development of information technology (IT) had made it easier for employees, users, suppliers and partners to interact and improve their business regarding the development of new products, marketing, distribution and customer services (Asosheh *et al.*, 2010). According to these authors, IT not only supports operations efficiently, but also helps in effective decision-making mechanisms and changes the way companies achieve a competitive advantage and organizational innovation.

When it comes to labor in the execution of a project, one is dealing with human resources that make up the project team. The structure of the team, defining the respective roles, the identification of skills and the association of those responsible for the activities in work packages are necessary, so that each work package is linked to a responsible person (Carvalho and Rabechini Jr, 2011). Skilled staff is one of the ten most important critical

International Journal of Managing Projects in Business

1753-8378
DOI 10.1108/IJMPB-09-2016-0074

success factors in the famous CHAOS report (Hastle and Wojewoda, 2015), which analyzes 50,000 software projects in the world.

Cost, time and scope are often used as measures of success in IT software development projects (De Bakker *et al.*, 2010). Much research recognizes that human resources play a critical role in the success or failure of an IT project (André *et al.*, 2011). A project in which the original budget is not adhered to by the parties involved as a result of a change will most likely invalidate the decision that led to its approval, i.e. it should not have been approved and carried out (Albertin, 2001).

The choice of how to manage the project is important so as to satisfy all stakeholders. Nowadays, the literature is showing the growth of agile methods of project management (PM) and their suitability for reducing uncertainty in projects (Serrador Pinto, 2015). However, they are riskier compared to traditional methods (Fernandez and Fernandez, 2008). The traditional method is more appropriate for projects where requirements, functionalities and features are well defined (Fernandez and Fernandez, 2008). This research will focus on this method that many organizations continue to adopt.

According to the PMI (2013), in a traditional method, the distribution process of the resources required for each activity is called resource allocation. This should be estimated within each period, as should the assumptions that determined the types of resources, their availability and quantities. The allocation should consider all the activities in the project work packages. Documentation of resource requirements must contain a level of detail that specifies the roles and responsibilities that may vary according the different application areas.

Another relevant aspect refers to the leveling of resources that are allocated to tasks, respecting the constraints of time and cost. The resources need to be allocated within legal labor standards, leveled as much as possible to have the lowest cost for a project, reducing idleness or the payment of unnecessary overtime (Huang *et al.*, 2011).

Classic methods, such as the critical path method (CPM) and project evaluation and review technique , have been used in PM since the 1950s. The major limitation of these methods is in building a project plan in practice that considers the constraints of resource availability and activity breaks (Ching, 2007). The conflict and the need for compensation between time, cost, and resource use in projects require negotiations to maintain the results agreed with the stakeholders.

Thus, procedures, models and proposed mathematical algorithms emphasize that their uses are designed to provide decision support for project managers and executives involved in the respective projects, regarding allocation, negotiation and prioritization. Yaghootkar and Gil (2012), Oh *et al.* (2012), Megow *et al.* (2011), Hegazy and Menesi (2010), Chen *et al.* (2012), Sarker *et al.* (2012), Taghaddos *et al.* (2012), Yang and Fu (2014) and Heravi and Faeghi (2012) clearly highlight this role of supporting decision making, but do not show a successful practical application. Another important point to highlight is the absence of human resources allocation and leveling in the literature for IT projects in general, and particularly, for IT infrastructure projects, where the human resources should be shared by a number of different projects due the specific competencies needed and have great difficulty in being leveled. This point aggregates the importance of this study to the investigation in order to propose a model to treat this problem.

Thus, this research aims to propose a model of allocation and leveling of human resources in an integrated manner in the planning of IT projects. It is a practical contribution for project managers to use a process to support their decision making to increase the probability of success in their projects.

2. Literature review

2.1 Resource allocation and leveling in projects

According the PMI (2013), a project schedule includes the planned dates of the beginning and ending of each project activity. This schedule remains in primary status until the pool

of resources in tasks has been confirmed and the start and end dates of the work schedule of these resources have also been confirmed. This association receives the name of resource allocation. The problem of allocation of human resources in IT specifically involves a group of professionals and a set of activities. Each professional has a number of features such as skills, knowledge, experience, academic background and certifications. Each of these characteristics has a certain intensity or unavailability. Project managers face frequently complex management situations due to limited resource availability (Koulinas and Anagnostopoulos, 2011). This unavailability can occur because of vacations, allocation to another activity in the same period, leave, training, among others (Barreto, 2003). Another problem is the limited number of resources. A resource allocation policy should be planned and this will strongly influence project duration (Lee *et al.*, 2007). Financial factors can also influence allocation. Hartmann and Briskorn (2010) point out that the allocation of resources in the carrying out of project activities results in demands for certain payments to be made when phases or parts of projects are complete, affecting estimated cash flow.

Resource leveling is conceptualized by PMI (2013) as a technique in which start and end dates of activities are adjusted based on the constraints of existing resources, in order to balance the demand for resource availability. According the PMI (2013), resource leveling can be used when required resources are shared, available only at certain times in limited quantities or over allocated (resource associated with two or more tasks simultaneously). It is important to note that the function of the costs to be minimized and the existence of a delivery date for the project, lead to a balance between the time and cost of the project: if more resources are allocated, the project can be completed faster since different activities can be performed simultaneously. However, the more resources allocated, the more expensive the project will be (Yamashita and Morabito, 2007).

2.2 Methods for project scheduling

To focus on the issue of resource allocation and leveling, various views, methods, techniques and mathematical algorithms are designed to reach a solution. Three methods will be discussed: CPM, resource constrained project scheduling problem (RCPSP) and resource leveling problem (RLP).

For the project schedule, the classic CPM helps in the calculation of estimated durations of tasks and the best time for the execution of the project. In its basic form, the CPM does not take into account the issue of resource management – human and material – assuming that these resources required by the project activities are unlimited (Koulinas and Anagnostopoulos, 2011). CPM is used to estimate the duration of the project and determine the amount of slack in the project schedule, considering the logical network of project activities (PMI, 2013). In any network tasks, the slack is measured by the amount of time a task can be delayed or extended without delaying the project finish date as a whole. The critical path of a project is obtained by the sequence of tasks that have slack equal to zero, i.e., any delay in these tasks affect the project finish date (PMI, 2013). The critical path analysis allows the project manager to make tradeoffs during the life cycle of the project. For example, if the project manager knows that a task on the critical path is delayed, more resources should be allocated to catch up in time. This provides the project manager with the points of attention in relation to deadlines (Schwalbe, 2013).

The RCPSP is a heuristic method that contains procedures to solve major problems that arise in practical cases (Roca *et al.*, 2008). The word "heuristic" is used generally to define generic methods for finding solutions to problems. For RCPSP, this term is used to indicate the methods that use prioritization and optimization rules (Brucker *et al.*, 1999). The RCPSP aims to answer the question: "Given the limited availability of resources, what is the best way to schedule activities in order to complete the project in the shortest possible time?"

(Roca *et al.*, 2008). Among the practical applications of a model like this, the RCPSP can basically be formulated mathematically as follows:

(1) a project is a set A of "n" activities, represented mathematically by the set $A = \{1,2, \ldots, n\}$, where each activity has a way of running and must be processed without interruption;

(2) there are two "dummy" (simulated) activities – the number 1 and the number "n" – representing the beginning and the end of the project, respectively;

(3) the duration of each activity A_j is represented by d_j, where $d_1 = 0$ and $d_n = 0$;

(4) there is a set of predecessor activities in an activity A_j (Pred_j) and a set of successor activities of this activity A_j (Succ_j) to represent the logical relationship between the start and finish of each activity; and

(5) there is also a number K of renewable resources that have availability for a period, which can be represented by R_k. Each activity A_j requires r_{jk} units of resource "k" during the period of its duration.

The goal of RCPSP is to find a schedule for the activities in the set A, in which the precedence and resource constraints are met (feasible programming) and the duration of the project (makespan) is minimized (Roca *et al.*, 2008).

The RLP is a particular case of RCPSP problem and many functions were used in the past to model RLPs in the real world (Koulinas and Anagnostopoulos, 2011). According to the authors, the main objective is to minimize the duration of the project, effectively reprogramming the activities of the project to find a feasible solution. This technique causes an increase in the total duration of the project in relation to that calculated by CPM, which assumes unlimited resources. Resource leveling seeks to reduce the total cost indirectly, mainly preventing hiring or layoff of human resources in the short term.

A decision support system is necessary to allow project managers to take decisions from many alternatives of allocation and leveling of resources, considering all the restrictions cited above.

2.3 Decision support systems

Only in the last century did the theory of decision become a formal element of decision-making support. Prior to this, humanity was taking decisions by making use of common sense, intuition or occasionally heuristics (Samson, 1992). Smith and Von Winterfeldt (2004) discuss the evaluation of prescriptive models for their usefulness in better decision making. Decision analysis helps to support decision-making processes and the intuitive and cognitive abilities of the decision maker. According to Clemen and Reilly (2013), the activities that make up a decision-making process are: identifying the problem, identifying goals and alternatives; decomposing the problem into structural models of uncertainty and preferences; choosing the best alternative; analyzing the sensitivity to determine the consistency of the solutions; deciding whether it requires more analysis; andimplementing the chosen alternative.

Also according to Clemen and Reilly (2013), there are at least four difficulties in making a decision: complexity of the problem – the problems have many possibilities that should be considered in order to be solved; uncertainty – for current status and future events, it is necessary to consider a series of events that may affect the problem, if they arise; multiple objectives to be achieved, given that when a decision is made in an attempt to achieve more than one objective, it is difficult to reach a balance between the objectives; and different perspectives, since the interpretation of the problem depends on who is solving it.

Decision support systems can be for individuals or groups of users. The support can be direct or indirect, and can range from a support that considers all the possibilities and

suggests the best options to decision makers, to a support that only provides information to the decision maker, so that they can interpret, analyze and decide (Mora *et al.*, 2002).

Software support is an indispensable item for several PM functions. Professionals make wide use of such PM software as Microsoft Project and Oracle Primavera©, mainly used for planning the critical path (CPM). The planning schedule and resource usage are shown in Gantt charts and histograms. However, the information provided varies in these packages and also when compared to theoretical results (Hazır, 2014).

Today, spreadsheets, such as Microsoft Excel©, are ordinarily used in all industries (Hazır, 2014). According to the author, they can perform many decision support functions as well as being able to implement many optimization models. For this reason, decision support systems based on spreadsheets offer significant potential applications (Hazır, 2014).

According to Hazır (2014), decision support systems must contain two major components: analytical models and solution algorithm models, which are the basis for simulation and optimization, and presentation of data and graphical interface. Executives usually consider many alternatives before making a decision. The representation in visual mode influences the quality of decisions, and graphs showing variations and numerical tables are defined as the most effective means.

2.4 Study propositions

Considering the specific objectives of the research question presented in this study, through a cross-analysis of the theoretical framework, specific points of the study that led to the proposals can be formulated, to establish a form of the proposed model.

According to the considerations of Schwalbe (2013), PMI (2013) and Hazır (2014), identifying the critical path should be used to estimate the duration of the project and determine the amount of slack in the project schedule. The planning and the corresponding allocation of human resources should consider delays in the project as a whole when there are gaps in the supply of resources with the desired skills. To ensure that the key success measures are met (De Bakker *et al.*, 2010), the project manager must generate a schedule that both includes all constraints regarding human resources and has adequate follow-up. A software tool as a support is recommended. This brings us to study proposition (P1): the organization identifies the critical path in all its projects.

The project can have many activities to be planned. The allocation of human resources should start with the critical path tasks so as not to impact the total duration planned for the project. The lack of human resources for carrying out a critical path task generates delay in a specific task and, hence delays the project as a whole. Kastor and Sirakoulis (2009) suggested beginning to allocate resources at the critical path stage to avoid this kind of delay. Hazır (2014) stated that software support is an indispensable item for several PM functions and Kerzner (2009) argued that the most sophisticated software package cannot substitute good project leadership but it can be an aid to the project manager in tracking the many interrelated variables and tasks that come into play in a project, such as critical path analysis, resource planning and resource leveling. Study proposition (P2) is thus established: the allocation of human resources should start in the critical path tasks.

Human resources are a critical factor for IT project success (André *et al.*, 2011), probably because resource constraint influences the development cycle and benefits of projects (Cheng *et al.*, 2013). Brucker *et al.* (1999) stated that the planning of a project has to take into account the distribution of resources in time-dependent activities. On this point, Roca *et al.* (2008) stated that the RCPSP should help the team to respond to the following issue: "schedule activities to complete the project in the shortest time," given the availability of resources. Thus, human resource constraints influence decisions in the allocation of these resources in project activities. These restrictions may be due to a lack of necessary resources in quantity or competencies, leave, vacations or they are already allocated to other projects, directly influencing the ongoing

cycle of projects and their benefits. Study proposition (P3) is thus created: human resource constraints require control of the quantity and competencies of those resources.

Oh *et al.* (2012) emphasized that the growth of a company is associated with a number of methods that help in decision support in projects for the development of a new product. Also on this topic, the issue of multi-project environments appears and consequently the exchange of resources between projects. Taghaddos *et al.* (2012) pointed out that the resources from a competing project need to go through an adaptation and require some time to start, thus lowering productivity in the project. While Yang and Fu (2014) proposed a model of decision-making responsibilities in resource allocation in multi-project environments, with a project prioritization committee, in constant negotiation with project managers and the project office (Project Management Office or PMO). This leads to study proposition (P4): the models and methods used for human resources allocation contribute to the decision-making process.

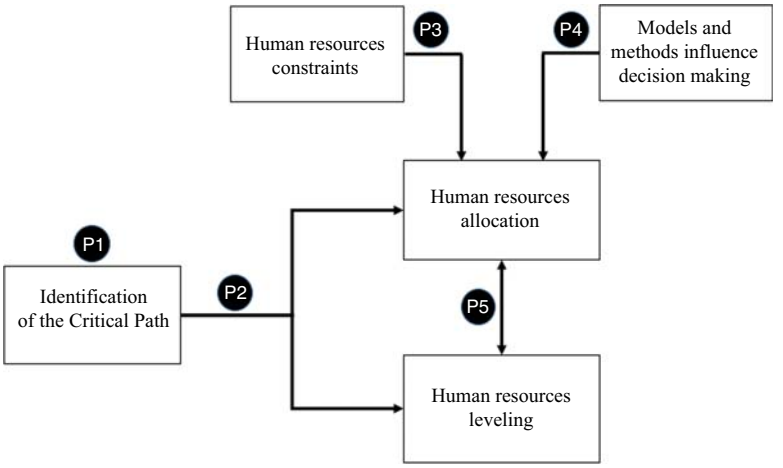
Megow *et al.* (2011) stated that in resource leveling, the different functions of the models and algorithms, such as the cost-time tradeoff, restrictions, hiring external resources, work shifts, leveling itself and risk analysis, are fundamental to the process of a project manager's decision. Hegazy and Menesi (2010) proposed the decomposition of the duration of each activity in separate time segments, with the objective of increasing the granularity and visualization of the allocation and consequent leveling of human resources in a project. Thus, it may be concluded that the leveling process needs to be done during the allocations. At the time of project planning, this leveling can be qdone simultaneously with the allocation, thereby proposing an optimal allocation. This simultaneous leveling can be done with the assistance of a software tool to support the decision. Therefore, the need to assess study proposition (P5) arises – Leveling can be done simultaneously with the allocation of human resources.

3. Research procedures

To meet the main objective of this study, which is to propose an integrated model of allocation and leveling of human resources in the planning of IT projects, empirical research was set up, classified as positivist, exploratory and qualitative. According to Yin (2015), using case studies as research strategy can be used in many situations, including organization and management studies. A case study is empirical research investigating a contemporary phenomenon within a context of real life, when the boundaries between phenomenon and context are not clearly defined (Yin, 2015). This method was chosen because there would be no possibility of control over the phenomenon within the limits of the defined research.

3.1 Model proposition

In order to generate the model, some propositions were established to be studied in an IT organization's projects. P1 will check the need to identify the critical path as a constant practice in the organization and the use of a software tool for identification. P2 will verify the importance of starting the allocation of human resources with the critical path, the collaboration of a software tool used and the difficulties encountered by the organization's project managers in the allocation of human resources, as well as frequency analysis and updating of information relevant to this allocation. With P3, how the constraints on the amount of resources and skills influence the allocation of management and human resource leveling will be checked. In P4, there will be a search to verify the influence of models and methods existing in the organization in the allocation of human resources and the participation of internal committees and occasionally the PMO in this process. P5 focuses on the management of the leveling of human resources and whether it can be done simultaneously with the allocation. Figure 1 shows the synthesis of the model proposed in this study.



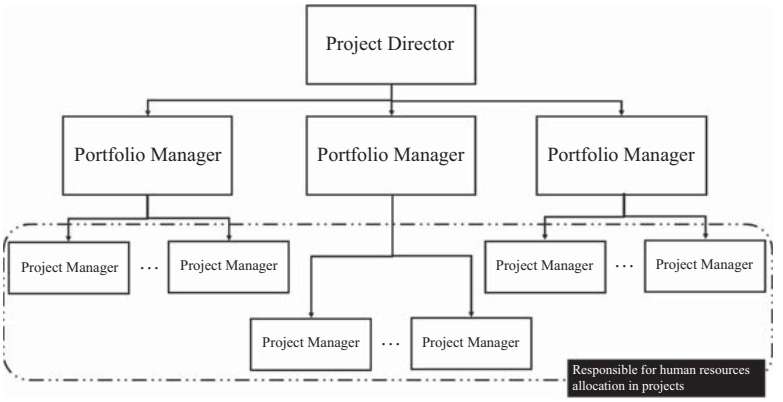
Source: Prepared by the authors

Figure 1.
Conceptual model

3.2 Unit of analysis

The unit of analysis of this research consists of an IT department and its projects. Yin (2015, p. 54) stated that a single case is relevant when it is "critical, peculiar, common, revealing or longitudinal." The chosen case is common, because the application of allocation and resource leveling is one of the activities set out in the organization's methodology, as well as being important so that it can meet demands efficiently. The case is also revealing because access to strategic information, classified documents and interviews with several participants of the phenomenon, which made the evaluation of the study's defined propositions possible. It is important to highlight that subunits of analysis in a single case study like this one, according to Yin (2015), may allow a good opportunity for analysis, improving the outcome of a single case study.

The case analyzed in this study comprises the management of IT infrastructure projects in an IT outsourcing service company, with annual sales of more than 700 million American dollars. The projects considered were in the period from July 2014 to December 2015, totaling 14 projects. Figure 2 shows the organizational chart of the department in which PM



Source: Prepared by the authors

Figure 2.
Organizational chart

is divided into three project portfolio managements that serve different client companies, in many market segments. The designation of a project (client) for a given portfolio manager simply follows the criterion of the one with fewer projects – balancing the number of projects, since the projects have the same size and complexity.

After client approval of the technical and commercial proposals, the project managers are responsible for project planning. The forecast of human resources with the right skills is one of the main items that make up the planning. These resources include, in addition to the organization's direct employees, the allocation of human resources from third-party suppliers of specialized labor as well as temporary or contingent resources. Project managers are responsible for the definition, negotiation and allocation of human resources for the planning of projects and were the focus of the interviews.

All respondents work in the area of IT Infrastructure Transition Project Management, which are projects where the client contracts the changes in its IT infrastructure to the data center of the company being analyzed, with updates and modernization of infrastructure. This change in infrastructure generally includes server hardware exchange activities (operating systems such as Windows, Unix and Linux) and networks, updates and database migration (Oracle©, SQL Server© and Big Data as SAP HANA©), information security deployment (networks and data), data load balancing and application version updates, such as SAP©. Although these migration projects have an activity execution standard, they have characteristics specifically contracted by each client, making each project unique. All these projects are treated as complex by the organization in question and have several activities with restrictions regarding running time. For example, they can only be performed outside business hours, which makes the issue of allocation and leveling of human resources of outstanding importance in the organization.

3.3 Data collection procedures

Appendix 1 presents the research and data collection protocol, with the questions asked and their relationship to the proposals under consideration.

3.3.1 Protocol for studying an integrated single case. According to Yin (2015), the protocol for a case study is more than a questionnaire. It is an instrument containing general procedures and rules to be followed. According to the author, the protocol is the main way to increase the reliability of research and it should guide the researcher in conducting the case study. Thus, for this study, the following protocol was developed:

(1) delivery to respondents of a description of the research being developed, along with the questions that would be raised;

(2) previous survey of the demographics of the respondents;

(3) organization of the interview:

- schedule the date, time and place of the interview;
- request authorization for the digital recording of the interview for purposes of clarity, reproduction and efficiency in the interview time, eliminating the need for notes; and
- inform the expected duration of each interview, which is about an hour; and
- inform the needs for documentation collection, such as a project plan, minutes of kick-off meetings and allocation of human resources planning.

A pre-test questionnaire with other project managers who do not belong to the organization in question was conducted. In this pre-test, there was no doubt as to the terms used and responses that could be provided. The questionnaire was sent in advance to the project

managers interviewed in the case study, but the fact that there may have been misleading answers due to a misunderstanding of expressions and terms used in the questionnaire cannot be discounted.

3.3.2 Data collected. We comply with three principles suggested by Yin (2015) to ensure the quality of data collection: multiple data sources, such as project documentation, project monitoring records and interviews; database with all kinds of data sources; and evidence chaining.

The documentation and records collected files are related to the project plan, the minutes of the kick-off of project meetings and the planning of allocation of human resources for these projects. We used the extraction of reports and documents available in the Microsoft SharePoint tool© used by the organization's PMO. The interviews were recorded with the interviewees' permission and transcribed by the authors using media player software as a support tool. In total, ten interviews were scheduled with project managers in December 2015 and they were held in the period of January 15-22, 2016. These interviews were conducted by one of the authors and both authors carried out the analysis. The duration of each interview was about 60 minutes, totaling 10 hours and 102 transcript pages.

A pre-test was conducted with other project managers not from the organization under review. At that time, there was no doubt as to the terms used and the answers that should be provided. The questionnaire was sent to the interviewee in advance to allow reflection on the subject and to ensure an efficient and productive meeting. At the end of each interview, it was estimated by the interviewer that the interviewee had commented on the allocation and leveling of human resources and used in this analysis.

To preserve the anonymity of the respondents and the organization analyzed, there was suppression of respondents' names in the transcripts; replaced by a type code "PGPnn" where "PGP" means "project management professional" and "nn" is a sequential number. Also to guarantee anonymity, the logos and names of the organization under consideration were excluded from documents and files, and fictitious names replaced individual ones.

3.3.3 Interviews. Table I shows the profile of the respondents. All work in the same department. It is important to note that all respondents have a first degree and six have completed a post-graduate qualification. Nine have professional certifications in the IT field, and four have the Project Management Professional certification.

It can be seen from Table I that there are two positions for the respondents: Project Manager I and II. The functional difference between these concerns the level of technical interaction and interaction in the managing of the project. The Project Manager I position has more intensive technical monitoring of performance and quality of the activities in the

PM ID	Position	Graduate	Post-graduate	Certifications	Time in the organization (years)	Time as PM (years)
PGP01	PM I	Yes	No	MCSE	4	1
PGP02	PM I	Yes	No	ITIL, COBIT	1	7
PGP03	PM I	Yes	No	No	1.5	11
PGP04	PM II	Yes	Yes	PgMP, PMP, PMI-RMP, ITIL	2	15
PGP05	PM II	Yes	Yes	PMP, MCSE	8	11
PGP06	PM II	Yes	No	CCNA, ITIL	7	8
PGP07	PM II	Yes	Yes	ITIL	1.5	5
PGP08	PM II	Yes	Yes	ITIL, COBIT, PMP	4	4
PGP09	PM II	Yes	Yes	PMP, ITIL	8	8
PGP10	PM II	Yes	Yes	MCSE	2	6

Source: Prepared by the authors

Table I. Interviewed project manager profiles

project than the management of all phases and activities of the project. These managers use the allocation information and leveling of human resources for the implementation of project tasks under their responsibility. The Project Manager II position has an effective role in PM in all phases and activities and is responsible for status reports within the organization and with the client, as well as being directly involved in negotiation regarding the allocation and leveling of human resources in the projects of the organization under analysis.

3.4 Procedures for data analysis

In this study, the general analytical strategy used was one of theoretical proposals combined with the use of qualitative data. Linking the research question, the theoretical framework, and the establishment of premises generated five propositions. Each proposition was pursued as follows: description of the information gathered in field research; analysis of the documentary evidence and electronic files extracted from the organization's internal systems; interpretation of the data, including the submission of any new findings, not described previously; and verification of the proposition based on practices found in the organization, classifying them into confirmed, partially confirmed or not confirmed.

Appendix 1 shows the 18 questions applied to project managers in the interviews, the documents and files assessed to validate the answers and the analysis made. The answers were then classified by adherence to the propositions.

Qualitative criteria based on practical activities and knowledge of those interviewed will therefore be established for a proposal to be considered confirmed, partially confirmed or not confirmed. According to Yin (2015), in an analysis of a case study, one of the strategies is to use a logic of suitability to a model. It was established that if the total of constant adherent responses in a proposition is greater than 90 percent, and the documents and files support this, the proposition is considered confirmed. This means that the organization uses the concept tested and sees value in it. If the total is between 60 and 89 percent, verified by documents and files, it will be considered as partially confirmed. This means that some managers use and value the concept assessed. Below 60 percent, it is considered that the proposition is not confirmed, and the organization does not understand its value.

4. Results and analysis

Table II shows the answers classified by adherence to the propositions (yes/no), which will be commented on in the propositions analysis descriptions.

Table III, which show the synthesis of the results of the proposal evaluation, based on the analysis carried out, was constructed using the data collected and analyzed in interviews, documents and organization files.

4.1 P1 – The organization identifies the critical path in all of its projects

It was observed that there is a lack of knowledge regarding the concept of critical path, as shown in the literature support, demonstrated by three project managers. All of them are in PM I position. There was an absence of knowledge shown by two project managers that the software tool used in the organization – Microsoft Project© – could identify the critical path. As quoted by interviewee PGP06, one of those who were unaware of the critical path, the meeting minutes do not make any references to critical tasks or the critical path. On this subject, it should be noted that one respondent did not know the concept of critical path. Despite this lack, in the triangulation process, it was verified that the project schedules (Microsoft Project©) and the identification of the critical path were done. On the other hand, in the meeting when the commercial area handed over the project approved by the client to the project area, there was no mention of the critical tasks or the critical path. This was observed in the minutes of meeting.

Proposition	Question	Adherence to proposition (yes)	Not adherent to proposition (no)	% of adherence
P1	1a	7	3	70
	1b	8	2	80
	Total	15	5	75
P2	2a	2	8	20
	2b	10	0	100
	2c	7	3	70
	2d	9	1	90
	2e	7	3	70
	2f	9	1	90
	otal	44	16	73
P3	3a	9	1	90
	Total	9	1	90
P4	4a	9	1	90
	4b	10	0	100
	4c	9	1	90
	4d	8	2	80
	Total	36	4	90
P5	5a	9	1	90
	5b	8	2	80
	5c	8	2	80
	5d	10	0	100
	5e	7	3	70
	Total	42	8	84

Source: Prepared by the authors

Table II. Adherence to the propositions

Proposition	Fulfillment
P1 – The organization identifies the critical path in all of its projects	Partially confirmed
P2 – The allocation of the human resources should begin with the critical path tasks	Partially confirmed
P3 – Human resource constraints require control of the quantity and competencies of those resources	Confirmed
P4 – The models and methods used for human resources allocation contribute to decision-making process	Confirmed
P5 – Leveling can be done simultaneously with the allocation of human resources	Partially confirmed

Source: Prepared by the authors

Table III. Summary of results

It was reported in interviews that one of the most critical paths for the organization's activities is procurement and they are always part of the critical path due to delays in contracts and receiving items. This statement was confirmed by the organization's project kick-off document, created in the client's presence, originally in Microsoft PowerPoint©.

The analysis and interpretation of interviews, documents and files revealed that although there is no clear concept of critical path for some of the project managers, most of them use this practice in all their projects, because the software standard used provided it. They also make use of the lessons learned to determine the critical path tasks (e.g. in procurement). Thus, the average adherence in questions to the proposition was 75 percent, considered partially confirmed.

4.2 P2 – the allocation of human resources should begin with the critical path tasks

Most project managers do not carry out the allocation of human resources starting with the critical path tasks identified. Only two project managers responded that the best practice

would be for the allocations to begin with the critical path tasks to avoid creating gaps and delays in these tasks and consequently delaying the project. In contrast, there was unanimity among respondents that if the allocation of human resources does not start with the critical path, the project may be delayed. This shows that, although the project managers affirm that it is necessary to start the allocation of human resources with the critical path tasks, this practice is not encouraged by the organization. This gap is identified clearly by PGP03: It (the project) will certainly be delayed and will have to leave people involved in the project over a longer period of time and therefore it already has an impact on allocation and project cost. Also, the client will not be very satisfied." In some schedules, it can observed that critical path tasks had generic resources associated, i.e., there is no planning of a human resource to be allocated to the task, indicating an allocation gap not defined as a priority in the planning stage for the critical path. Regarding the software tool used (Microsoft Project©), there was a majority of opinions on the contribution of this tool in allocations. Interviewee PGP06 again responded that they were unaware of a tool to indicate the critical path and PGP10 indicated that they did not see a direct collaboration of the software tool for the allocation of human resources.

On the question of the difficulties encountered in the allocation of human resources in the projects, there were nine agreements that summarize the availability of these due to the sharing of resources between projects (multi-project environment) and the need to have the resources with the necessary skills. These items are the basis of PGP03's response, "it is always n projects and n activities." PGP04 comments: "*The second difficulty I see is in relation to competence. We do not always have the people with the skills necessary for project execution.*" Only PGP06 indicated that the biggest problem is the loss of autonomy faced by project managers in the allocation of human resources, suggesting that this was due to the creation of a department in the organization, called resource allocation management (RAM) (Resource Allocation Management), which has a database with the allocation of the organization's human resources.

Nine project managers answered that the update frequency of this database is weekly, although there cannot be a weekly update of some projects (resources have not changed). They indicated the new RAM department as the area responsible for the weekly meetings for negotiation and allocation of human resources, which project managers and functional managers of human resources are required to attend. The RAM department and the delay in the project due to erroneous allocations – client dissatisfaction were considered as new findings.

Thus, as the average adherence to this proposition was 73 percent, it is considered that it was partially confirmed through the practices found in the organization. The analysis and interpretation of interviews, documents and files revealed that although there is no stimulus procedure for the organization to begin the allocation of human resources with the critical path tasks and project managers have indicated their experiences in following this procedure. Also, the creation of RAM helped in the negotiating procedures for allocating human resources in projects.

4.3 P3 – human resource constraints require control of the quantity and competencies of these resources

Just one project manager replied that they did not know how the company manages human resource constraints. The other nine respondents said that management is carried out based on cost and level of competence, citing activities or areas responsible in the organization with this function, and six of them cited RAM as being directly responsible for the management of human resource constraints, both in quantity and skills. Through the internal organization documents, it was found that there is a computer system that stores this information in a database. These data are stored and updated on a weekly basis through the results of negotiations held by an internal committee, people allocation

committee (PAC), sponsored by RAM, composed mainly of functional resource managers and project managers since the organization works in a matrix structure. At the end of the weekly committee meeting, a spreadsheet in Microsoft Excel © is distributed to all areas of the company, with the names of the resources, their skills and allocations for the duly agreed periods of time.

Therefore, with 90 percent compliance, it is considered that P3 was confirmed through the practices found in the organization. The analysis and interpretation of interviews, documents and files revealed that the creation of the RAM department in 2015 improved the allocation of management and human resources skills of the organization, which adheres to the theoretical references presented.

4.4 P4 – the models and methods used for human resource allocation contribute to decision-making process

There was almost unanimous agreement that the method used for allocation is the one that RAM applied. The exception is PGP02, who said that they did not work in this activity. PGP04 pointed to a new criterion for allocation, when a project has greater financial penalties because of delays. PGP04 commented, "you say the following: I have two projects to deliver and the first has no penalty and the second has a penalty for non-delivery. This is a deciding factor, which is to avoid a penalty that is a loss for the company."

Regarding the question of taking into account human resource vacations and days off for decision making, respondents said that these are taken into account, but there is little chance of having this information in the allocation of resources, as the projects are long – more than six-months – and there are few ways of knowing holidays or days off taken by human resources in advance. On this issue, PGP04 mentions a new situation for the prioritization of allocations coming from the top management of the organization, named internally in the organization as escalation. PGP04 said that to some clients time is very critical: "The client has total freedom to make contact with our executive layer, be it the vice-president or the president. So, there is a pressure sometimes because of escalation or penalties."

PGP02 and PGP03 ignored the role of the PMO in the allocation of human resources, but the other eight respondents made it clear that the organization's PMO has no active participation in human resource allocation activities. Once more, PGP04 clarifies the situation: "The PMO is not involved in this, perhaps unlike other organizations. In allocating resources, the PMO does not act, it is RAM that does so."

Regarding vacations and days off, it was found that early control is required. However, there are reactive and not preventive actions in the organization, due to the fact that the resources were already allocated when they requested vacations and holidays. With this need found as a necessary practice, in a process within a method of allocation of human resources, it is understood that this proposition with 90 percent compliance in the answers was confirmed through the practices found in the organization. The analysis and interpretation of the interviews, as well as documents and files, revealed that there is a method used by project managers, which is RAM and weekly meetings (PAC), to deliberate and take human resource allocation decisions. As a final input, the PMO in this organization has no active participation in the allocation of human resources.

4.5 P5 – leveling can be done simultaneously with the allocation of human resources

Regarding visualization and monitoring of the allocation in a specific period of time, PGP02 said they did not work with this process and have no insight into it. Two project managers (PGP01 and PGP09) said they use Microsoft Project© for this function. PGP03 considered RAM to be responsible for providing this view. The other six project managers said they maintain direct contact with human resources to always have an updated view of the

allocation due to the multi-project environment in the organization. This is necessary because the human resource activity date can be changed without the due immediate updating in RAM. PGP07 explains this problem: "That's another problem too, because it's another area we have no way of measuring. It's not something we can control. I cannot say to my resource that he/she has 8 hours of work on day 17."

On the subject of leveling, a different problem appeared. Most project managers are concerned about doing leveling, but they have great difficulty in achieving this goal because of the availability of resources. The resources have simultaneous operations in other organization projects, which make this process difficult for project managers. The spreadsheet provided by RAM shows the allocation in the projects and hours that a human resource will work per month, but does not include any visual aid for periods of time (e.g. days or weeks) for quick verification and practice of under- or over-allocation, making it difficult for project manager administration.

On the point of simultaneous allocation and leveling of human resources, two project managers do not believe this procedure is possible and the other eight express their support, but with caveats regarding the organization's internal procedures. PGP04 sums up the issue with the following statement "To have a well-done allocation and leveling of human resources, we would need to have a very detailed planning of the entire project at the beginning, which we do not usually have. The project will be detailed as it is being executed. It is difficult to have a view of everything in the beginning." However, all project managers indicate that they would use a software tool to perform this function. Four of them – PGP01, PGP04, PGP07, PGP08 – recommend Microsoft Project© and PGP09 recommends Microsoft Project Server©, linked to a Sharepoint portal© with a management dashboard with indicators.

For the visualization of allocations and leveling by task or fixed periods of time, three project managers preferred the view by task and the other seven said that the display per period of time would be ideal. PGP04 says: "I think in the ideal world, this would be a good target. Mainly because very long tasks are more difficult to manage and also, the allocation of resources in the task may vary." PGO05 states that "Visualization per period is best." and PGO07 affirms "it would help more to visualize per period of time." PGP01 adds the following description, "It would be easier and simple." Although Microsoft Project © for single projects or Microsoft Project Server© for multi-project environments provide this type of information, they do not include a proper graphical interface nor a what-if analysis interaction type, which is believed to be important in the process of supporting decision making, as pointed out in the literature support.

Consequently, with 84 percent compliance, it is considered that P5 was partially confirmed through the practices found in the organization. The analysis and interpretation of interviews, documents and files showed that while the project managers are concerned about doing the leveling of resources using a software tool, the organization in question has problems in directing these procedures due to competition for human resources between simultaneous projects and consequently in doing adequate leveling.

4.6 Proposal for operating model

4.6.1 Suggested model. With the contribution of literature support and analysis of the conducted case study, it was possible to propose the theoretical model for allocation and leveling of human resources in IT projects in an integrated manner in the planning stage. Figure 3 shows the flow of the final proposed model.

In this model, it can be observed that the first activity to be carried out for planning the allocation and leveling of human resources in IT projects is to identify the critical path. This activity is important for visualizing where there are time gaps in tasks that can result

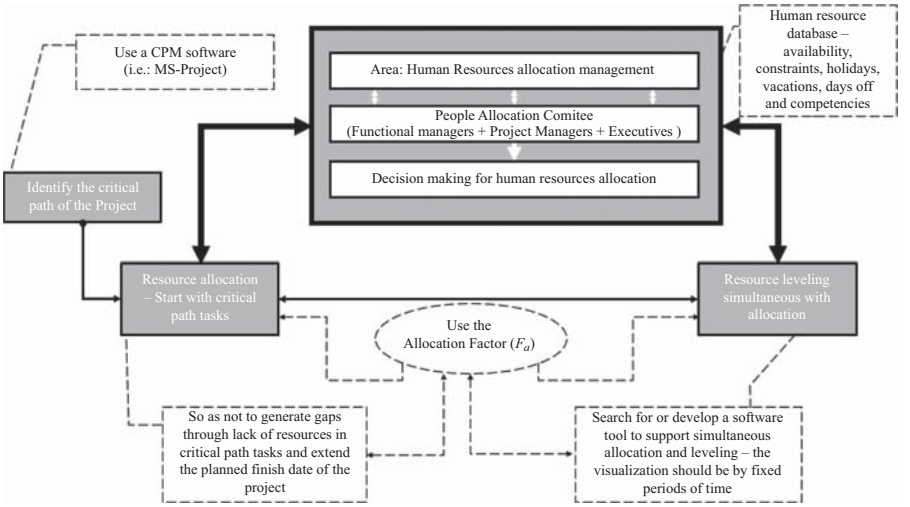


Figure 3.
Proposed model

in delays in the project. The use of a software tool with a feature for critical path calculation by the CPM method is recommended. An important point that arose in the case study was the need for a human resource management area capable of working in IT projects. This will maintain a centralized database with information on availability, constraints, vacation, days off and competencies of human resources. This area will be associated with a personnel allocation committee, with regular meetings, to make the final decisions regarding allocation and leveling of human resources in IT projects.

Project managers responsible for allocation and leveling must constantly interact with the human resource allocation management area and its committee, to make the decisions regarding availability of human resources in their projects clear. The use of a suitable software tool to gain a view of allocations and integrated leveling is recommended.

For implementation of this model in the organization under analysis, a number of actions should be set in motion. These actions could include:

(1) Formalizing the concept of critical path, its mandatory identification for all projects, with the support of Microsoft Project© software, by means of training and procedures to be strictly observed.

(2) Initiating the planning allocations of each project from the critical path tasks in order to comply with the planned dates, with a guarantee of resources for the execution of these tasks.

(3) RAM and PAC should have a suitable software tool to visualize under/over allocations, and leveling, to serve as decision support. As PGP09 puts it: "My suggestion would be Microsoft Project Server linked to a SharePoint portal with a management dashboard with indicators."

(4) The area of the organization suggested for monitoring and implementation of this model would be the PMO, since it acts as a direction area, as highlighted by PGP10: "The PMO provides one more guideline and some inputs." *P*GP06 states that "The PMO, from the perspective of human resources, no longer acts. They work more on artifacts and documentation." The RAM remains the area responsible for the resource database and interface with executives and project managers

through the CAP, with the PMO responsible for developing standards and procedures, as well as for the audits in the verification of compliance with these standards and procedures.

(5) One of the issues raised by the interviewed project managers was collaboration in having a preview of the allocation and the leveling of human resources in a fixed time period; not only the number of hours worked, but also whether the resource in this period is under allocated or over allocated, or allocated and leveled ideally to support decision making. It is suggested that a specific index should be defined to show the allocation and leveling to be used, along with a decision support tool. This tool could be Microsoft Excel© with a database search interface in the RAM database or Microsoft Project©, providing graphical user interface and tables, with the data being processed by formulas and/or specific programming, for what-if analysis. Another interface can return the final data (decision), to update the original database or Microsoft Project© for the agreed allocation and leveling. This index proposed for support will be named here as Allocation Factor.

The difficulties in implementing this model can be: the need for a specific budget, including software procurement; the financial and technical support for the implementation of an appropriate software tool; changes in responsibility designations and development of standards and procedures for the allocation and resource leveling. These actions will influence other areas of already existing procedures, such as vacation and days off policies, hiring, training for competencies, ongoing assessment of these competencies, as well as constant interaction with the various areas of the organization.

4.7 Allocation factor definition

According to the proposition by Hegazy and Menesi (2010), called critical path segments (CPS), it is interesting to increase the granularity of analysis of resource allocation by decomposition of the duration of each activity in fixed time segments. The use of the mathematical concept of the allocation factor (*Fa*), illustrated in Figure 4, is suggested.

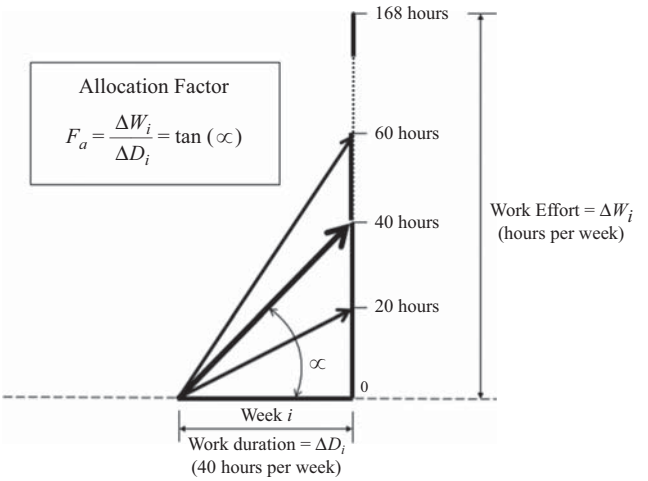


Figure 4.
Allocation factor (*Fa*)

If one week is used as the chosen time segment (which contains 40 working hours per human resource), for a generic week "*i*," the length and direction of the arrow are given by the effort (work) made by the resource within the week. In this week "*i*," the resource can work less than 40 hours and become under allocated or can work more than 40 hours this week and be over allocated or, in the ideal situation, work 40 hours and be ideally leveled (neither idle nor working more than expected, doing overtime). Thus, F_a may be defined, indicating the direction of the arrow as the allocation meter, which is proportional to the angle α shown in Figure 4, as the tangent of the angle α, by mathematical definition. It shows the allocation status of a resource by time interval taken for analysis. Table IV shows an example using a week as a time interval.

5. Conclusions

To meet the objective of proposing a model of integrated allocation and leveling of human resources in the planning of IT projects, the single case study method was applied, based on interviews with ten project managers of various levels of seniority, as well as on multiple documents: reports used by the organization's PMO, project plans, the minutes of kick-off project meetings and allocation of human resources planning.

In building the literature base regarding current practices, important items emerged, such as the need to identify the critical path, having critical path tasks as a starting point for human resource allocation to avoid delays in these tasks and consequently the project, issues regarding the quantity of resource constraints or also the sharing of these resources with other projects in a multi-project environment. Other points presented in the literature were related to methods or models that support decision making, a centralized database with human resource availability and constraints and competencies, the leveling of human resources running simultaneously with the allocations and software tools suggested for the purposes identified as Microsoft Project© and Microsoft Excel©. These practices served as the basis for formulating the study proposals presented in this article, which, in turn, served to outline the protocol applied as well as the analysis carried out.

Regarding the concerns for a process to support the decision for the allocation and leveling of human resources in IT projects, the need proved to be relevant in the conducted case study. A model used by the studied organization was presented, consisting of an area responsible for a database of human resources concerning availability, allocations in progress and competencies. This area organizes a weekly committee with the participation of executives, functional human resource managers and project managers, who, through the prioritization of projects and negotiations, collaborate for final decisions on allocation updates and leveling of human resources in projects. If the decisions are well thought out and implemented, they help on the issue of allocations more directed toward necessary skills and costs within the established budget, avoiding reworking, missed deadlines, increased costs and noncompliance with the expected quality of the project deliverables.

Situation	Allocation	Interpretation	Allocation factor (*Fa*)
Not allocated	$\Delta W_i = 0$; $\Delta D_{i>0;}$	Resource will not work in the week	0
Under allocated	$\Delta W_i < \Delta D_i$	Resource will work less than 40 hours in the week	< 1
Over allocated	$\Delta W_i > \Delta D_i$	Resource will work more than 40 hours in the week	> 1
Ideal leveling	$\Delta W_i = \Delta D_i$	Resource will work 40 hours in the week	1

Source: Prepared by the authors

Table IV. Allocation measurement in the week "*i*"

Although the analyzed organization had difficulty in carrying out the leveling of human resources because of the actions of the resources across multiple simultaneous projects and work outside business hours, such as migration of databases and IT systems, most respondents said that a process of allocation and leveling of human resources run simultaneously would be of great value.

In addition, a model for the process that integrates the allocation and leveling of human resources in IT projects was built, as shown in Figure 3, through the arguments and discussions presented, derived from evidence from interviews with project managers, files and documents of the analyzed organization was proposed. Through the practices highlighted in this model, an organization can allocate and level human resources in their IT projects in an integrated way.

The identification of the critical path as the first step of the process inside the model means that the directioning of the first allocations is toward the tasks that are part of the critical path. This guarantee the deadline planned for the project is met, respecting the competencies required of human resources for these tasks. After that, allocations should continue in the other project tasks, respecting the same restrictions and needs.

In order to have availability of information and competencies of human resources, the model suggests a human resources database, with availability, vacation restrictions and days off clearances, as well as the necessary skills, with constant updating of a specific area or department of the organization. This can occur in regular meeting of a special committee for the allocation of personnel, with the participation of executives, functional human resource managers and project managers.

Along with the allocations, the committee's decisions should promote the leveling of human resources in an integrated manner as a basic requirement of the project's time control and costs. In this meeting, many negotiations and conflicts occur. The prioritizing of allocations can take place according to the level of influence and power of the executives who make decisions; in the same way, clients who spend the most in the organization being studied can influence these prioritizations. Leveling can also suffer this influence and, as shown in this study, the limiting factor is the availability of these resources during overtime, since the leveling is jeopardized by the urgency of the activities being carried out in the projects, causing work impositions and, consequently, team demotivation.

This study demonstrates the importance of training professionals prepared to deal with the theme of allocation and leveling of resources in projects, considering the executives, project managers, human resources managers and the human resources who actually deal with IT projects. Despite this knowledge being considered basic in the literature, it can be noted that not all managers know and/or use it. Therefore, developing professionals with this knowledge allows an organization to have a better perspective regarding the use of its human resources and occasional gaps in availability and competences. This organizational reality certainly raises essential questions to be better dealt with in practice and theory.

One further contribution provided by this study is the existence of an area and a committee in an organization, responsible for the allocation and leveling of human resources, which facilitate the organization of a project's human resource data, among which are competences and skills, availability and allocation restrictions, as well as promoting and facilitating negotiations between distinct areas and projects, allowing more assertive decision making for allocations. These areas and committees have proved to be facilitators for project managers, transmitting security and commitment to the allocations supplied.

The final contribution is the model presented, which can be applied in the organization analyzed, so as to introduce improvements in the existing process, or in others that are similar, despite the need for empirical validation of the proposed model.

The main limitations of this study are: use of data of one company in the IT industry, making it difficult to create a general model for other sectors; it was noted during interviews that the project managers interviewed do not always know all the company's processes for allocation and resource leveling in detail, due to the large number of processes and different management activities of these professionals.

As a future study, we suggest validation of the model through action research, with the suitability of the model for the organization studied. The construction of a specific software to support decision making and optimization of algorithms is also suggested, as well as the development of interfaces between existing software on the market and the one to be developed. Also regarding future research in organizations providing outsourcing services, studies referring to allocation and leveling of resources in pre-sales could be considered, as well as in priority projects where the rate of return is high.

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Appendix

Interview Question	Documents and files	Analysis
P1 P1a. How is the critical path of a project identified in your organization? P1b. What CPM type software tool, is used for the purpose of question P1a?	CPM type software tool files to identify the critical path (e.g. Microsoft Project files©) Project documents from the proposal approval phase transferred to the project team Documents from the kick-off meeting with the end customer	Analyze how the organization identifies the critical path in the planning of their projects and how this identification occurs
P2 P2a. From which project tasks do the allocation of human resources begin? P2b. If the allocation of human resources does not start with the critical path tasks, what can happen? P2c. Does the software tool used help or hinder this process in some way? P2d. What are the difficulties you encounter in the allocation of human resources in your projects? P2e. At what stage is this information – critical path and allocation of human resources – used in the project? P2f. How often is this human resource allocation information updated?	CPM type software tool files with the identification of human resource allocations Internal committee or PMO documents with the allocation of human resources	Analyze whether the organization allocates its human resources from the critical path tasks
P3 P3a. How does your organization manage human resource constraints related to the amount of these resources and their skills?	CPM type software tool files with the identification of human resource allocations Internal committee or PMO documents with the allocation of human resources	Analyze whether there are restrictions of human resources and what the influence on the development cycle and benefits of projects is
P4 P4a. Which model or method is used in your organization for decision making in the allocation of human resources in projects? P4b. How are human resource holidays and days off considered for allocation of these resources? P4c. How are the decisions of the organization's committees considered in human resource allocation decisions? P4d. What are the guidelines provided by the PMO for the allocation of human resources in your organization?	CPM type software tool files with the identification of human resource allocations Internal committee documents or from PMO with the allocation of human resources	Analyze which models and methods the organization uses for decision-making in the allocation of human resources in its projects
P5 P5a. How do you view the allocation of human resources in a given period of time?	CPM type software tool files with the identification of human resource allocations	Analyze whether the organization works the concept of leveling of human resources

Table AI.
Research protocol and data collection

(*continued*)

Interview Question	Documents and files	Analysis
P5b. How do you treat the leveling of human resources in your projects? P5c. Would you do allocation and resource leveling simultaneously? P5d. Would you use a software tool for this? P5e. Do you think target tasks in fixed time segments help to visualize allocation and leveling?	-Internal committee or PMO documents with the allocation of human resources	and its application and whether this activity is carried out simultaneously with the allocation of these human resources

Source: Prepared by the author

Table AI.

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